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A COMPARATIVE TEST AND EVALUATION OF  
LEAD-BASED-PAINT TEST KITS

THESIS

Lynn S. Hill, P.E.

AFIT/GEE/ENP/93S-01

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LEAD-BASED-PAINT TEST KITS

THESIS

Presented to the Faculty of the School of Engineering  
of the Air Force Institute of Technology  
Air University  
In Partial Fulfillment of the  
Requirements for the Degree of  
Master of Science in Engineering and Environmental  
Management

Lynn S. Hill, B.S., P.E.

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## Preface

The purpose of this study was to evaluate chemical test kits for the detection of lead in paint. The intent of the research was to develop a standard evaluation procedure for follow-on studies and assess the baseline performance of the kits.

Tests were conducted with five kits on sample paint films of known lead concentrations. Interferences in the makeup of the paint caused two sodium sulfide kits to fail with 100% false positive readings for lead. Two sodium rhodizonate kits failed due to 100% false negative readings. One sodium rhodizonate kit provided positive and negative readings that varied as expected depending on concentration. In spite of these difficulties, the research provides a basis for test kit evaluation and information on the problems that can be encountered when performing chemical spot tests.

I owe several people thanks for their guidance and support in completing this research. My advisor, Lt Col Richard Hartley, and reader, Major Brian Woodruff, provided a balance of direction and guiding questions that was invaluable in identifying the scope of my research. Dr. Mary McKnight of NIST often gave of her valuable time to lend her expertise and offer suggestions. Many hours were put in by Mr. Robert Hendricks to conduct the required testing and record the data. I also thank the personnel at

HQ AFCESA/ENM who suggested the research and arranged for the preparation of the paints. Finally, I am forever indebted to my wife and children for putting their own lives on hold to come here and support me and provide balance to my life.

Lynn S. Hill

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Abstract

This research compares the performance of five chemical spot-test kits on lead-based paints. The kits are designed to give a qualitative assessment of lead in paint. The intent of the research effort was to develop a standard evaluation procedure for follow-on studies and assess the baseline performance of the kits.

The test kits in this study use either sodium sulfide or sodium rhodizonate to react with the lead. The presence of lead is indicated by a color change. The kits were used to test prepared sample paint films at seven known lead concentrations ranging from 0.04 to 1.3% by weight. The study was designed to minimize variables such as paint composition, paint age, layered combinations of paints, type of substrate, and user training.

Two sodium sulfide kits failed with 100% false positive readings. Two sodium rhodizonate kits failed due to 100% false negative readings. The remaining sodium rhodizonate test provided positive and negative readings that varied as expected with concentration. For this kit, probabilities of detection were calculated and a performance curve was generated and compared to a discomfort curve.

# A COMPARATIVE TEST AND EVALUATION OF LEAD-BASED-PAINT TEST KITS

## I. Introduction

### General Issue

Although people have known about the serious health effects of lead ingestion for thousands of years, the problem of lead poisoning still exists. The main focus of concern today is the effect that lead has on children. The Centers for Disease Control labeled it as "the number-one environmental problem facing America's children" (30:3). Construction workers also have a significant risk of exposure to lead. The National Institute for Occupational Safety and Health (NIOSH) issued a Health Hazard Alert in 1991 concerning lead poisoning of construction workers (21:38).

One of the biggest potential sources of lead exposure for humans is lead-based paint (21:39). In the past, lead was a common pigment in paints. As these old paints wear, children can be exposed to the lead by ingesting paint chips or paint dust that gathers in the home. A serious hazard also exists for construction crews who perform renovation and demolition work where leaded paint is present.

The concentration of lead in paint varied over the years depending on the manufacturers and regulations. Lead concentrations ranging from 0% to 65% by weight (% w/w) can be found in any facility built prior to 1977 (7:2). In 1977 the Consumer Product Safety Commission (CPSC) set 0.06% w/w as the maximum allowable concentration of lead in household paint but did not limit its use in industrial paints (4). Therefore, the potential for lead exposure exists at a wide range of concentrations in any age or type of facility.

Several agencies have conducted studies to determine the extent and location of leaded paint in housing. In a 1990 national survey, the U.S. Department of Housing and Urban Development (HUD) found that "74 percent of all occupied housing units built before 1980 have lead-based paint somewhere in the building" (8:3-6). According to the survey, the likelihood of encountering lead-based paint and the concentrations expected vary depending on the type of surface. For example, they found lead-based paint much more often on molding than on walls (8:3-21).

Because of the large number of pre-1980 homes, it is impractical to treat all of them as if they contain leaded paint. The time and cost of abatement are prohibitive. HUD estimates that the average cost for removal of paint in a housing unit is \$11,870 (8:4-11). By this estimate, it would cost the Air Force nearly 1.5 billion dollars to remove the paint from its pre-1980 housing units. Testing

and inspection methods have to be used to identify and prioritize lead paint hazards.

### Paint Testing

Several means of analyzing for lead in paint are available. This research divides the analysis methods into three groups: laboratory testing, quantitative field testing, and qualitative field testing.

Laboratory analyses of paint samples are usually conducted by either Atomic Absorption Spectroscopy (AAS) or Inductively Coupled Plasma (ICP) Spectroscopy. Laboratory testing is more precise than field testing but is also more costly, more time consuming, and less convenient (7:46).

Portable X-Ray Fluorescence (XRF) is the method used most often in the field to obtain a quantitative measurement of lead in paint (9:25). XRF equipment can present a radiation hazard and requires extensive training and experience to obtain acceptable readings (7:41; 9:A13-12). This equipment is initially expensive to purchase but repeated use eventually lowers the cost-per-sample below that of full laboratory analytical testing.

Chemical test kits are available to provide a qualitative field test for lead on painted surfaces. These test kits provide an indication of the presence or absence of lead above some detection level. Even though the chemical tests cannot determine the amount of lead in paint,

they can serve as an inexpensive screening tool if their detection levels and reliabilities can be determined. The HUD Lead-Based Paint Interim Guidelines, generally accepted as the industry standard, do not allow for the use of chemical test kits because they have "not been adequately validated" (9:25). However, in a report prepared for HUD, the National Institute of Standards and Technology (NIST) recommends:

Evaluation of [chemical] spot tests should be continued to assess the causes of erroneous results and to investigate variabilities in results due to the tester and to paint film properties. (7:48)

#### Air Force Requirements

Current policy requires all Air Force installations to identify existing lead paint hazards but not all have the means to do so efficiently (12). Many Air Force bases do not have on-base laboratories to perform analyses for lead in paint. These bases must send samples for laboratory analysis to another base or to a local lab which significantly increases cost and turn around time.

The Air Force intends to use portable XRF equipment to survey housing and other facilities (11:9). Current plans are to purchase one XRF analyzer for each base bioenvironmental office. It is expected to take from one to two years to receive the analyzers and, once they are obtained, bases will only be able to test about two housing units (6 rooms each) per day (24). The priority facilities

for inspection by the bioenvironmental office will be those that are frequented by children (11:3). It will be logistically impossible for each renovation or demolition job site to also be checked by XRF.

To protect themselves and building occupants, civil engineering work crews need a quick and accurate way to screen for the presence of lead on painted surfaces. The most likely way to meet this need is with chemical spot tests. Unlike the HUD guidelines, the recently released (24 May 93) Air Force Guidance on Lead-Based Paint allows for the use of chemical spot tests (11:9,10). Civil engineering crews could use these kits to check for lead before working with painted surfaces and to prioritize the XRF testing.

#### Problem Definition

The Air Force Civil Engineering Support Agency (AFCESA) recommended this research effort to determine if any of the commercially-sold lead test kits has the potential to be used by Civil Engineering to screen for lead on painted surfaces. To make a recommendation, AFCESA needs to know the detection level, reliability, and ease-of-use of each kit (24). The detection level or sensitivity is the lead concentration at which the kit reliably identifies the presence of lead in the paint. For this research, the detection level is defined as the concentration where at least 95% of the tests result in positive readings.

Reliability here refers to the ability of the kit to repeatedly give the same results, whether positive or negative, at a given lead concentration. It encompasses both repeatability of results by a single user and reproducibility of results by multiple users. The reliability of producing a positive result is the same as the probability of detection.

The reliability and detection level of a test kit at various lead concentrations can be evaluated by developing a performance curve (41). All of the test kits should have an upper concentration range at which all readings are positive for lead detection, a lower concentration range at which all readings are negative, and a transition range between the two. A plot of the probability of detection versus lead concentration defines these regions and creates the performance curve. The detection level is then identified by the curve at the point where the probability of detection equals 95%.

The Air Force has adopted an action level of 0.5% w/w of lead in paint (11:8). If the lead concentration is at or above 0.5% w/w, protective measures are taken before removing, sanding, or cutting the painted surface. The usefulness of each test kit depends on where the transition region of its performance curve occurs relative to the action level of 0.5% w/w.

False negative and false positive readings are defined with respect to the action level. A false negative reading is any negative result when the lead concentration is above 0.5% w/w. A false positive reading is any positive result when the lead concentration is below 0.5% w/w. Therefore, if the lead concentration is below the action level, a positive reading will still be considered false even though lead is actually being detected.

The acceptable rates of false positive and false negative readings are not equal. False positive readings have the effect of needlessly spending money to mitigate a hazard when none exists. A false negative reading creates the risk of allowing a health hazard to go unmanaged and thereby allowing someone to be exposed to a hazardous substance. A decision maker must determine for each situation what level of comfort is required for each type of error. For example, the decision maker might accept a 10% chance of wasting money but only a 5% chance of exposing someone to an unknown hazard. A plot of the acceptable probability of each type of error versus the magnitude of risk is sometimes called a discomfort curve (18).

#### Test Kit Evaluation

To provide a definitive answer to the AFCESA question, the performance of each test kit needs to be evaluated under multiple conditions. The test procedures under all



conditions must be standardized so that the test results can be compared and combined. The important parameters for standardization are test kit brands, sampling procedures, units of measure for lead concentration, and data reporting methods. These parameters were not standardized for the previously conducted studies of test kits. As a result, the tests are difficult to interpret, impossible to compare, and provide only fragmented pieces of information on the abilities of the kits.

The lead paint concentrations used for testing should be extended across the range that bounds the detection levels of the kits. The greatest number of concentrations and the greatest number of samples per concentration need to be in the region where the readings transition from positive to negative. The results can then be reported in terms of probability of detection as a performance curve and the acceptability of performance can be compared to a set discomfort curve.

The test kit evaluations must be completed systematically to evaluate the influence of various parameters. The performance of the test kits can be influenced by paint composition, type of lead pigment, paint age, layered combinations of paints, sample homogeneity, type of substrate, and user training. A complete assessment of the performance of the kits will require an individual evaluation of how each variable affects kit performance.

The assessment should begin with the establishment of a baseline performance curve for each kit. This baseline will provide a comparison to evaluate changes in performance from all other variables. Next, the variables that can affect performance should be analyzed individually in the laboratory by carefully controlling all other variables. The assessment would then proceed to field testing with variables controlled as possible. Some parameters such as paint composition, paint layering, and type of lead pigment will be unknown in field testing. Other parameters such as substrates and user training are controllable. Although it is tempting to try to obtain a final answer with massive field tests, a systematic building of a data base facilitates the compilation and interpretation of test results in the long run.

### Objectives

The purpose of this research is to develop a standard evaluation procedure for follow-on studies and assess the baseline performance of the kits. The procedures used in this study, with adjustments as necessary, are recommended as the basis for a standard evaluation. Establishing a baseline requires the elimination of all other variables except kit brand and lead concentration. For this research effort, substrate type, paint composition, paint age, paint layers, and user training were all held constant and all

testing was done under laboratory conditions. This was done to provide a best-case analysis of the performance for each kit.

The evaluation of the baseline performance curve for the test kits required the following steps:

- 1) Define the discomfort curve.
- 2) Determine what qualitative test kits are available.
- 3) Select a lead concentration range for testing.
- 4) Test each kit on a common basis under controlled conditions.
- 5) Determine the probability of lead detection for each kit at selected lead concentrations.
- 6) Plot baseline performance curves based on the probabilities of detection and compare to discomfort curve.

### Limitations

Many different lead compounds have been used as pigments and driers in paint. The most common one in older paints was basic carbonate white lead (25:351). However, it is no longer in use even in industrial paints (35). The leaded paint used in this research effort was a yellow industrial paint pigmented with lead chromate. Although not as common in older paints as basic carbonate white lead, it has been used as a pigment in both the commercial and industrial paint industries and is indicative of paint that could be encountered in the field (25:380).

Monetary and time constraints limited the number of leaded paint concentrations that could be prepared. Also limited were the number of tests that could be conducted by each kit at each concentration. Testing could not be done to determine the minimum detection level of each kit. The concentration range used for the testing bounded the action level of 0.5% w/w so that the performance of the kits were evaluated within the range where the kits would be most useful.

Once the presence of lead is established, the question of how to deal with it arises. This research does not cover any abatement options. A variety of management alternatives have been developed and are already being used. The method of preference depends on the types and locations of the painted surfaces. Civil engineering personnel will be trained in methods of lead paint management that can be used after the presence of lead has been identified (11:17).

## II. Background

### Introduction

One of the main sources of lead for lead poisoning of humans today is lead-based paint in housing and other facilities (21:39). As with housing in the rest of the country, lead-based paint is a potential problem in military housing. The Air Force recently (24 May 93) released policy and guidance documents to begin to investigate the scope of the problem (11; 12).

To appreciate the significance of the problem of lead-based paint, this section presents information on the toxic effects of lead and on the use and regulation of lead in paints. A comparison of the historical information to the age distribution of Air Force housing shows that the Air Force can expect to find large numbers of housing units with lead-based paint. Next is a presentation of the primary available means of testing for lead in paint. Analyses can be performed in the laboratory by spectroscopy or in the field by X-Ray Florescence (XRF) or chemical spot tests. Each method has advantages and disadvantages relating to accuracy, portability, usability, and cost. Finally, the section reviews the results from previous testing of chemical spot tests.

### Lead Exposure

Lead is a cumulative poison which collects in the blood, liver, bones, kidneys, and brain. Some of the symptoms of severe lead poisoning include headache, weakness, hyperactivity, reproductive difficulties, insomnia, and joint pain (10:2). Problems may also result from low doses of lead. Low IQ scores and developmental problems in children have been found to occur at low blood lead levels that were previously thought to be harmless. A combined analysis of several studies on lead's effect on IQ concluded that there is "a strong link between low-dose lead exposure and intellectual deficit in children" (28:677).

Children. Lead affects children more than adults for several reasons. Children are more likely to ingest available lead because of their behavioral habits. Their play area is typically on the floor where leaded dust from paint and soil collects and they are more likely to put paint chips and dirty hands in or near their mouths. Ingested lead is absorbed at a higher rate in children than in adults. The absorption rate for children is approximately 50% of ingested lead whereas the absorption rate for adults is about 10% (31:6). A higher absorption rate and lower body weight per dose make even small amounts of ingested lead a potential problem for children. The problem is also compounded for children because lead hampers development. The brain during childhood is especially

sensitive to the effects of lead because of the rapid growth that occurs in those years (31:2).

These factors are causing a sense of urgency around the country in dealing with sources of lead and lead poisoning of children. Because of studies showing that even low blood lead levels can cause harm, the government recently reduced the acceptable level of lead in the blood of children. The new level at which action must be taken to reduce blood lead levels is 10 micrograms per deciliter (mg/dL) of blood (22:252). The previous limit was 25 mg/dL.

Construction Workers. Another target group for concern is the construction industry. Construction workers often perform renovation, demolition, and maintenance work on facilities where lead-based paints are present. Some estimates suggest that tens of thousands of construction employees are affected by lead poisoning (30:3). In August of 1991, the National Institute for Occupational Health and Safety (NIOSH) issued a Health Hazard Alert for construction workers. NIOSH warned that operations such as sand blasting, cutting, sanding, and welding of surfaces with lead-based paints create a significant lead exposure hazard (21:38).

The construction industry has historically received less protection from lead exposure than has industry in general. The permissible exposure limit for construction workers is approximately 4 times that for general industry

(3:37). Studies show that even the higher, construction industry standard can be exceeded by a factor of 100 during abrasive blasting operations (10:4). Problems with providing protection for high levels of lead are compounded by Environmental Protection Agency (EPA) requirements that the dust be confined in the work area (30:4). Until the mix of standards can be worked out, NIOSH recommends that construction crews follow general industry standards when working with potential lead-paint surfaces (36:67).

### History

Lead compounds were used as pigments all over the world for thousands of years (17:56). Around the turn of the twentieth century, basic carbonate white lead gained a great popularity as a white base paint pigment. It gave to paint qualities of adhesion, toughness, elasticity, and durability (25:352). Many countries realized the hazard that lead pigments posed for human health and by 1921 lead-based paint had been banned in Australia and many European countries (27:287). Unfortunately, the United States did not join in the ban at that time. In fact, old federal specifications for white-lead paints required lead concentrations of approximately 65% by weight (% w/w) in the dry paint film (7:2). The paint industry used other lead compounds besides basic lead carbonate as pigments and driers in paint at various concentrations. Some of the common compounds are



basic sulfate white lead, leaded zinc oxide, lead chromate, lead sulfate, and red lead (25:352-385).

Manufacturing Regulation. After World War II, concerns over the potential problems of exposure to leaded paints grew and the use of lead in paint decreased. In 1953, the paint industry voluntarily reduced the level of lead in house paints to 1% w/w (5:533). Realization that lead-based paints were still posing a serious problem of lead exposure resulted in another voluntary cut to 0.5% w/w in 1962 (5:535). However, without regulation it is difficult to know which manufacturers actually followed the industry standards. Even after the voluntary industry cuts, concentrations as high as 20% - 25% w/w could be found in primers purchased by government agencies under federal specifications (35).

Continued problems brought about federal regulation of leaded paints through passage of the Lead-Based Paint Poisoning Prevention Act in 1971 (9:4). From 1973 to 1977 the Consumer Product Safety Commission (CPSC) considered 0.5% w/w to be a safe level of lead in paint (8:1-3). The final restriction on lead in the manufacture of surface coatings for consumer use went into effect on 27 Feb 78. The CPSC made the following declaration:

Paint and similar surface-coating materials for consumer use that contain lead or lead compounds and in which the lead content...is in excess of 0.06 percent of the weight of the total nonvolatile content of the paint...are banned....

(4)

However, this requirement did not cover paints sold for industrial, agricultural, traffic marking, or building coatings (4). In June 1981, the Air Force adopted the same limit of 0.06% w/w for lead in paint used in housing units (13).

Painted Surface Regulation. Separate requirements exist for lead-based paints that were applied prior to the manufacturing regulations. Action must be taken to remove or control the deterioration of paint whenever the concentration of lead is greater than or equal to either a mass-per-area concentration of  $1 \text{ mg/cm}^2$  or a weight percent of 0.5% w/w (9:2). The two different units of measure are used to accommodate the available means of testing for lead in paint. These concentrations are set for federally administered housing. States and other regulatory agencies can set levels that are more stringent. The Air Force adopted the 0.5% w/w standard but, lowered the acceptable mass-per-area concentration to  $0.5 \text{ mg/cm}^2$  (11:8).

There is not a simple relationship between the two standards. The conversion from % w/w to  $\text{mg/cm}^2$  depends on the density and thickness of the leaded paint film. The

equation for conversion is

$$[Pb] = \frac{w/w * d * t}{100} \quad (1)$$

where  $[Pb]$  is lead concentration ( $\text{mg}/\text{cm}^2$ ),  $w/w$  is percent lead by weight,  $d$  is paint film density ( $\text{mg}/\text{cm}^3$ ), and  $t$  is paint film thickness (cm) (7:2). Equation (1) is represented graphically in Figure 1 assuming a film density of  $2000 \text{ mg}/\text{cm}^3$ , a thickness-per-coat of  $0.005 \text{ cm}$ , and a uniform lead concentration in all coats (7:53). Using these assumptions,  $0.5\%$   $w/w$  and  $0.5 \text{ mg}/\text{cm}^2$  are equal at ten coats of paint. Since housing units receive a coat of paint about every three years (the average length of stay of military

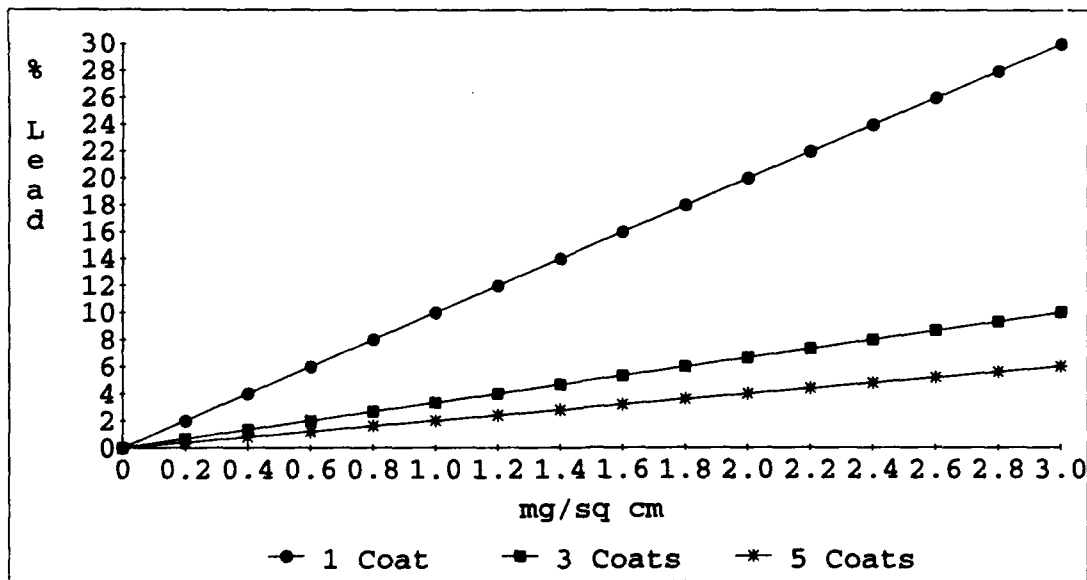


Figure 1. Correlation of Percent by Mass to Mass per Area of Lead in Dry Paint Films (Assumes thickness of  $0.005 \text{ cm}$  per coat and film density of  $2000 \text{ mg}/\text{cm}^3$ ) (7:53)

personnel) and the average age of the units is 31 years, ten is a good estimate of the average number of layers of paint in an Air Force housing unit (33).

Use of two different units of measure makes comparison of test results difficult. Figure 1 shows that a single coat of paint containing up to 5% w/w, ten times the percentage criterion, still passes the Air Force 0.5 mg/cm<sup>2</sup> criterion. Similarly, multiple coats with lower weight percents of lead can be acceptable based on mass-per-unit-area. On the other hand, if a composite paint sample is taken from a surface for analysis, leaded paint can be diluted by layers of nonleaded paint and result in a low weight percent of lead. The painting history of the surface determines which of the two units of measure is more conservative.

#### Lead Distribution

A variety of possible exposure levels exist in all facilities around the country because of the gradual changes in lead use for paints. The *Air Force Policy on Lead-Based Paints in Facilities* states:

Lead-based paint is likely to be found in all industrial facilities, on all steel structures (water tanks, pipelines, etc.), in yellow painted pavement markings, and in non-industrial facilities constructed prior to 1980. (12:2)

National Distribution (8:3.1-3.33). In a 1990 report to Congress, HUD presented the findings of a national survey of lead-based paint. The report gives an estimate of the

percentage of houses that have lead-based paint on any interior or exterior surface. Figure 2 summarizes the results of the survey. The chart shows the percentage of housing units where lead exceeded 0.7 mg/cm<sup>2</sup>, 1.0 mg/cm<sup>2</sup>, or 2.0 mg/cm<sup>2</sup>. It can be seen from the chart that the proportion of high lead concentration decreased significantly in later years. The HUD survey found lead-paint concentrations greater than 0.7 mg/cm<sup>2</sup> on an average of 70% of exterior surfaces and 66% of interior surfaces. HUD also found that the incidence of lead-based paint varied by component. The most frequent occurrences were on metal items such as radiators and heat vents, and on moldings such as window sills, crown molding, and stair trim.

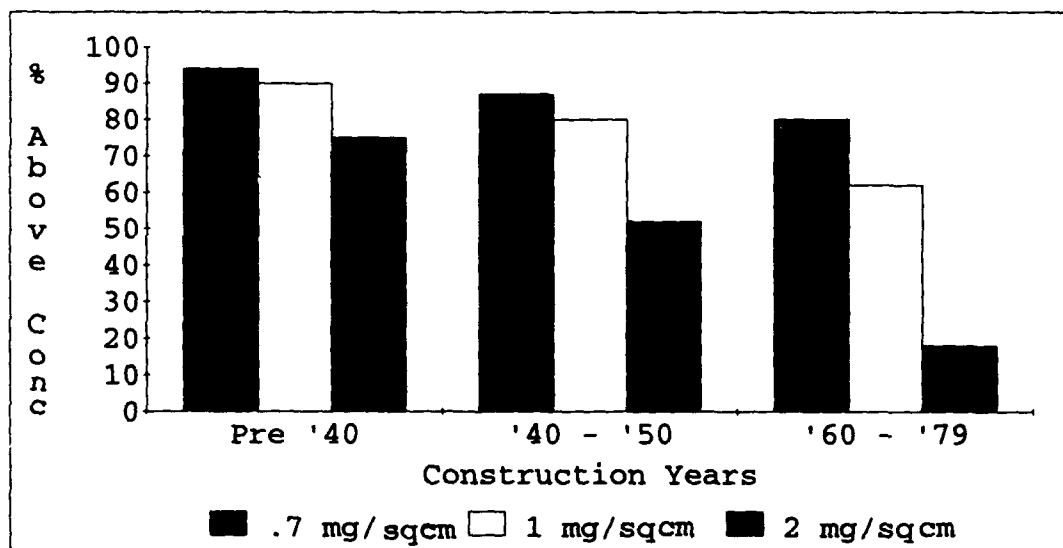


Figure 2. National Distribution of Lead-Based Paint by Concentration and Period of Construction (8:3.9)

Air Force Distribution. Only a few Air Force bases have conducted surveys to investigate the extent of lead-based paint. Armstrong Laboratory conducted one such study at March Air Force Base in California (38:1-10). The survey consisted of a sample of exterior surfaces on 51 housing units out of a total of 147 in the Green Acres Housing area. Approximately 90% of the units sampled had lead-based paint on at least one exterior surface and 60% of the 206 total samples collected had lead concentrations greater than 0.5% w/w (38:7). No information is given in the report on the age of the housing.

Armstrong Laboratory also conducted a survey at the Griffiss Annex Housing, Hancock Field, New York (37:1-9). The units were approximately 32 years old and both inside and outside surfaces were tested on 28 out of a total of 216 units. The survey found that "over 90% of the window sills in the dining room and living room, and the outside walls tested positive" (37:7). The report does not state what lead concentration was used as the action level for the survey.

There are currently about 129,000 units in the Air Force with an average age of 31 years (33). Figure 3 shows the approximate age distribution of Air Force housing. The figure shows the number of housing units built during each half decade and also displays the approximate number of units built in each period that might be expected to contain

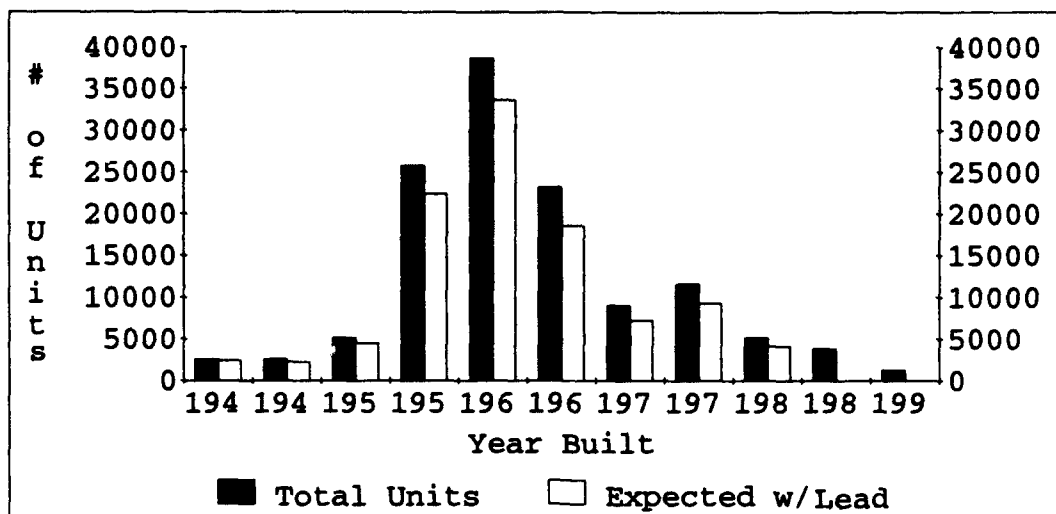


Figure 3. Age Distribution of Air Force Military Housing and Expected Numbers of Units Containing Lead-Based Paint (8:3-9; 33)

lead-based paint. The estimate of expected numbers with leaded paint is based on the HUD survey findings of housing units with more than  $0.7 \text{ mg/cm}^2$  (8:3-9). Using this basis, the Air Force can expect to find nearly 105,000 units with lead-based paint on at least one surface. Since the Air Force standard is  $0.5 \text{ mg/cm}^2$ , actual numbers may be even higher. This does not mean that all of the paint would be removed from all 105,000 units. Abatement would only be required on the surfaces testing positive for lead.

### Testing

Several methods of testing for lead in paint are available. The analysis methods can be divided into three groups: laboratory testing, quantitative field testing, and

qualitative field testing. Each method has advantages and disadvantages and conditions under which they are either effective or ineffective.

Laboratory Testing. Laboratory testing for lead in paint is generally done by either Inductively Coupled Plasma (ICP) Spectroscopy or Atomic Absorption Spectroscopy (AAS) (16:1). Both methods require extraction of the lead from the paint sample and into solution. Approximately 40 methods exist for extracting lead from paint films (1:1059). Research Triangle Institute conducted a study of some common methods for the EPA. Using ICP to analyze the extract, they found that lead recovery rates ranged from 41.6% to 95% for several standard extraction procedures (1:1065). Since only the extracted lead is detected by the analysis equipment, the accuracy of the laboratory procedure is more dependent on the efficacy of the extraction procedure than on the type of equipment used (1:1065).

An EPA publication of standard operating procedures for use of AAS and ICP notes some differences in the performance of the two methods (16:2-5). The publication reports that the typical detection range of lead in paint is wider for ICP than AAS and ICP is more sensitive by about a factor of ten. However, both are capable of accurately detecting lead in paint below 0.1% w/w. The EPA publication reports that neither method has significant interferences from other



chemicals in the extract. Both methods provide results in terms of percent lead by weight.

The disadvantages of laboratory testing are time and cost. The procedures used in the laboratory cannot be carried out in the field. They require that a paint sample be removed from the surface and sent to a laboratory for analysis. Depending on the location of the laboratory, turnaround time can vary from a few days to a few weeks. The cost for analysis of each sample is around \$30 - \$35 (8:4-4). Because of the time and cost, laboratory analysis cannot feasibly be used as the only method of testing to complete a survey of military housing units. Its most important use is for confirmatory testing when results from other methods are inconclusive.

Quantitative Field Testing. The HUD guidelines for lead-based paint state that "the preferred method for testing paint in housing is the portable XRF" (9:25). The guidelines also explain the functioning of an X-Ray Florescence (XRF) detector:

This instrument x-rays the paint on the surface, causing lead in the paint, if present, to emit a characteristic frequency of radiation, the intensity of which is measured by the detector and related to the amount of lead in the paint.  
(9:25)

The primary advantage of these instruments is that they give an immediate indication of the amount of lead in the paint without removing or defacing the paint.

Two types of XRF detectors are available. They are the direct-reading XRF and the spectrum-analyzer XRF (7:6; 9:25-27). The direct-reading XRF, as the name implies, gives a direct readout of the calculated lead concentration. The spectrum-analyzer distinguishes the lead x-ray radiation from the radiation of other elements and can display a graph of the intensity of each. Both types of XRF give results in terms of mass-per-unit-area. The equipment is initially expensive to purchase (around \$20,000) but repeated use will eventually result in a low cost per test (24).

Studies of the direct-reading XRFs raise some concerns about their accuracy particularly in the range of  $0.5 \text{ mg/cm}^2$  to  $1 \text{ mg/cm}^2$ . The type of substrate under the paint probably has the greatest effect on the accuracy of XRF equipment. A study conducted by the National Institute of Standards and Technology (NIST) found that "the precision of measurements over wood was generally poorer and the systematic error higher than over plaster or gypsum wallboard" (7:38). Another study found problems with false negative readings on dense substrates such as brick and concrete (29:4). NIST concluded that when corrections for the type of substrate are not made (the operator is inexperienced or bare substrate is not available), readings of  $4 \text{ mg/cm}^2$  or greater must be obtained to have 95% confidence that the true concentration is greater than  $1 \text{ mg/cm}^2$  (7:46). With substrate correction, the standard deviation for readings

over wallboard is approximately  $0.7 \text{ mg/cm}^2$  so readings of about  $2.5 \text{ mg/cm}^2$  are required for 95% confidence.

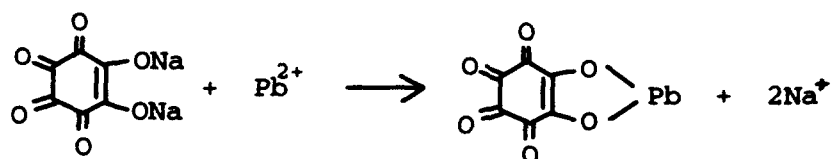
Because of the penetrating energy of the XRF devices, it is possible to obtain false positive readings from subsurface items such as wires, pipes, flashing, or an old wall enclosed by a new one (7:47; 29:6). The problems with substrate and subsurface interferences require that the operator of an XRF be trained and experienced in the corrections, adjustments, and confirmatory laboratory analyses that may be required before a reading is accepted as accurate.

The Air Force guidelines call for use of the spectrum-analyzer XRF (11:9). NIST found that the spectrum-analyzer XRF is significantly more accurate than the direct-reading XRF (6:5). The estimated standard deviation for readings over either wood or plaster is  $0.35 \text{ mg/cm}^2$ . NIST concludes that a reading from a spectrum-analyzer without correction for substrate is more accurate than a corrected reading from a direct-reading XRF.

Qualitative Field Testing. In an attempt to meet the need for rapid screening tests in the field, entrepreneurs market test kits intended to evaluate lead in paint. The cost of the kits ranges from \$0.30 - \$1.35 per test. These kits are for consumer use and are, therefore, relatively easy to use. The tests can be performed with the paint left

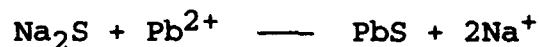
in place, but, some defacement is required to expose all of the paint layers.

The kits are based on one of two chemicals. One of the chemicals used is sodium rhodizonate. Sodium rhodizonate reacts with lead to form a complex which is pink or red in appearance. The reaction is as follows (23):



Other metals also react with sodium rhodizonate and result in a similar complex. The ones most likely to be encountered in paint testing are copper, iron, magnesium, and zinc (23).

The other commonly used chemical is sodium sulfide. It combines with lead by the following reaction to form a gray or black compound.



Other metals that also form black metallic sulfides are copper, mercury, cobalt and silver (2:17). However, one manufacturer of a sodium sulfide kit states that "if [these metals are] present at all in residential paints, they are in amounts small enough not to interfere with the *in-situ* test for lead" (40).

Probably the most commonly used basic white pigment today is titanium dioxide. There is disagreement between

two sodium sulfide kit manufacturers as to whether or not titanium dioxide creates an interference problem. One manufacturer states that "actual testing of titanium dioxide with sodium sulfide showed no color change" (40). The other warns that "modern paint uses metals like titanium dioxide that turn a gray color when reacted with sodium sulfide" (19:16).

There are several disadvantages to the use of chemical spot tests. In order to expose all of the layers of paint to the chemical, the surface has to be cut or sanded. The surface is also discolored by the chemicals. Some touch-up of a tested surface is usually required. Another problem is that the test kits only provide an indication of the presence or absence of lead; the amount of lead in the paint cannot be determined. However, chemical spot tests can serve as a useful tool for a quick and inexpensive screen. The reliability of chemical spot tests under the many variables of field conditions has not been thoroughly evaluated (9:25; 7:48). Several studies have been conducted and research is on going to determine the sensitivity and reliability of the chemical spot tests.

Previous Research. J.W. Sayre and D.J. Wilson conducted one early assessment of spot tests for lead in paint (32:783-784). Their testing focused specifically on the use of sodium sulfide to test for lead. The lowest concentration tested in the study was 0.8% w/w. At that

concentration, the sodium sulfide solution resulted in "a faint gray color" indicating that the detection level is less than 0.8% w/w (32:784). The sodium sulfide also seemed to provide semi-quantitative results by gradations of color from gray to black depending on the lead concentration.

In 1976, the Naval Facilities Engineering Command conducted additional testing on sodium sulfide solutions (6). Details of the test conditions are not given in the report. However, the report provides the following statement concerning the sensitivity of the sodium sulfide solution to lead in paint:

Conveniently, approximately 0.5% was the minimum concentration of lead that could be detected in light-colored paints by the sodium sulfide reagent. The minimum concentration that could be detected in dark-colored paints would no doubt be greater than 0.5%; and it would obviously be impossible to detect lead in black paints by means of the sodium sulfide reagent. (14:5)

This suggests that the detection level of sodium sulfide is near the action level of 0.5% w/w. The statement also points out that it is difficult to distinguish the color change on dark paints when using sodium sulfide.

The Navy also conducted tests on the useful life of a sodium sulfide solution. They report:

[Sodium sulfide will] remain sensitive for many months in well-stoppered containers. If the containers are not covered, the reagents rapidly lose hydrogen sulfide and become insensitive to lead. (14:1)

An extended life may enhance the cost effectiveness and convenience of sodium sulfide.

HUD conducted tests with sodium sulfide to evaluate its reliability on paints with lead concentrations above 0.7 mg/cm<sup>2</sup>. In this study, HUD used sodium sulfide to test 377 sites in 37 housing units (8:D-6). Laboratory analyses verified that all of the sites had lead concentrations in excess of 0.7 mg/cm<sup>2</sup>. The report provides no information on whether the concentrations were close to, much greater than, or spread out from 0.7 mg/cm<sup>2</sup>. HUD instructed the technicians on the use of sodium sulfide but none of them had previous experience with lead paint testing. Since the concentrations were all above the set action level, all negative readings counted as false negatives.

The results show a poor reliability and indicate that reliability varies by type of substrate. Wood substrates had a 25% false negative rate and all other substrates combined had a 50% false negative rate. Based on these findings, HUD does not recommend the use of sodium sulfide as a negative screening tool (8:D-7). In other words, HUD does not consider it safe to accept negative readings as an indication that lead is not present. Since the report does not provide concentration details, it is not possible to say at what concentration reliable positive readings are obtained.

The Georgia Tech Research Institute conducted a comparative analysis of several test kits for the EPA (20). In this study, three untrained individuals conducted the tests. The individuals tested each of four samples once with each kit. The samples came from a public housing development and were first analyzed by XRF (20:1). Two samples had lead concentrations  $< 0.1 \text{ mg/cm}^2$  (lead free), one was  $1.0 - 1.7 \text{ mg/cm}^2$ , and one was  $> 3.0 \text{ mg/cm}^2$  (20:6). Table 1 summarizes the results of the Georgia Tech study (20:16).

These results suggest that the detection level for sodium sulfide is above  $3.0 \text{ mg/cm}^2$ . Since the units of measure are different and the concentration is only reported as greater than  $3.0 \text{ mg/cm}^2$ , it is difficult to compare this result to the Sayre or Navy tests. However, it exceeds the

Table 1. Summary of Results From Georgia Tech Study of Lead Test Kits

Type of Kit	Concentration of Lead ( $\text{mg/cm}^2$ )	Total Samples	Number Positive
Sodium Sulfide	$< 0.1$	6	0
	$1.0 - 1.7$	3	0
	$> 3.0$	3	1
Sodium Rhodizonate (Kit # 4)	$< 0.1$	6	0
	$1.0 - 1.7$	3	1
	$> 3.0$	3	3
Sodium Rhodizonate (Kit # 5)	$< 0.1$	6	1
	$1.0 - 1.7$	3	1
	$> 3.0$	3	3



action level of 1 mg/cm<sup>2</sup> by at least a factor of three. The report states that the testers had difficulties discerning the color change with the sodium sulfide test (20:15).

The two sodium rhodizonate kits gave essentially the same results. Again, because the concentrations are given in such broad terms, it is not possible to identify the detection level for sodium rhodizonate more precisely than above 1.0 mg/cm<sup>2</sup>. Therefore, these kits will apparently also give a significant number of false negative readings above the action level.

The Georgia Tech study qualifies all of the results in the report with the following statement:

Since only three testers were used with a limited number of samples, it is impossible to regard these results as conclusive. Additional tests should be performed to confirm these findings.  
(20:15)

NIST conducted laboratory and field testing with both types of chemical spot tests (7:21-34). For the laboratory testing, NIST mixed a basic carbonate white lead paste with an oil-based paint to give paint films with lead concentrations of (in percent lead by weight) 0.14, 0.28, 0.7, 1.4, and 2.8. Two individuals conducted all of the tests. They each conducted one test per paint film with each chemical. For the field testing, NIST identified sites using XRF as either greater than or less than 1 mg/cm<sup>2</sup>. Several laboratory technicians conducted the field testing

and recorded total numbers of positive and negative readings at each site.

The findings of the laboratory tests are inconclusive. All of the sodium sulfide tests gave positive readings. The sodium rhodizonate tests were all positive for one operator and positive except at the two lowest concentrations for the other operator. These results could be due to interferences from other elements in the paint. They could also mean that the detection level of sodium sulfide is less than 0.14% w/w and the detection level of sodium rhodizonate is near 0.28% w/w under these laboratory conditions .

The results of the field tests are reported as reliabilities above and below 1 mg/cm<sup>2</sup>. With sodium sulfide, NIST obtained a false negative rate of 10% at the sites above 1 mg/cm<sup>2</sup> and a false positive rate of 12.5% at the sites below 1 mg/cm<sup>2</sup>. The sodium rhodizonate gave an 11% false negative rate above 1 mg/cm<sup>2</sup> and an 8% false positive rate below 1 mg/cm<sup>2</sup>. These results show better reliabilities than HUD obtained with its sodium sulfide tests. However, because of the lack of information on actual concentrations, it is impossible to determine what biases may exist from concentrations that are high, low, or close to the action level.

In spite of some of the discouraging findings, the possibility of using chemical spot tests has not been abandoned. Because of conflicting results and the potential

for chemical tests to provide a quick, portable, and inexpensive test for lead in paint, the recommendation from all of the previous tests is that further testing should be done. However, the tests described above demonstrate the need for systematic, standardized testing of the chemical test kits. The previous tests used varying units of measure, small sample sizes, multiple variables, and different data reporting methods. Without carefully controlled variables and an established performance baseline for comparison, test results will continue to be disconnected bits of information.

### Conclusions

The Air Force can expect to find significant problems with lead-based paints at all Air Force bases. Lead in housing units should be isolated to those units built before 1980. However, since lead was not banned in paints for industrial purposes, office, maintenance, and storage buildings of any age could be suspect.

Because of the high susceptibility of children to lead poisoning, the first priority should be to make housing and child care centers lead safe. However, any area where maintenance is to be performed should be checked for lead so that maintenance workers are protected. Accurate tests for lead can be run in the laboratory but the time required will cause substantial delays in projects. Chemical spot test

have the potential to provide quick and inexpensive screening for lead in paint once their capabilities are established. This research effort is to develop a standard evaluation method for all follow-on studies and assess the baseline performance of the kits for comparison of future results.

### III. Methodology

#### Introduction

Several government agencies have conducted evaluations of lead-based paint chemical test kits. However, past analyses of lead test kits have lacked continuity. They did not have standards for lead concentration, variable control, sampling, or reporting. The studies used small sample sizes ( $\leq 5$ ), one or two of the available kits, varying surfaces, different units, or complicated extraction procedures. As a result, the tests are difficult to bring together to make a conclusion about the performance capabilities of lead test kits. This research is intended to provide a standard basis for testing and reporting and to evaluate the baseline performance of the available quantitative lead test kits.

Field tests of lead-based paint have many more variables and interferences involved than the laboratory tests conducted for this research. The conditions used in this research effort purposely eliminated variables in paint layers, substrate material, paint age, paint composition, and user training. Each of these variables has the potential to change test kit performance. Conditions were controlled and the number of variables minimized to determine a best-case, baseline performance for each of the kits.

### Test Kit Selection

Research Triangle Institute provided a list of seven manufacturers of lead paint test kits used in testing performed for the EPA. The list contained the following manufacturers:

1. LeadCheck Swabs, Hybrivet Systems, Natick, MA
2. Frandon Lead Alert, PACE Environs, Scarborough, Ontario
3. E.M. Lead Test, E.M. Science, Gibbstown, NJ
4. The Lead Detective, Innovative Synthesis Corp, Newton, MA
5. Acc-U-Test, Hingham, MA
6. Orbeco Analytical Systems, Farmingdale, NY, and
7. Hach Company, Ames, IA

The first five in the list are spot test kits based on one of the two chemical reactions described earlier. Numbers 1, 2, and 3 use sodium rhodizonate and Numbers 4 and 5 use sodium sulfide. They provide a qualitative analysis by indicating the presence of lead. The last two are more quantitative in nature. They require colorimeters, complex extraction procedures, and extraction chemicals and equipment. Because these two are in a different class from the others, they were not selected for consideration in this research.

The LeadCheck kit contains one-piece swabs in cardboard outer tubes. Each swab is about the size of a cigarette. Inside of each cardboard tube are two breakable vials that,

when crushed, mix the leaching and indicating reagents into one solution and wet the swab tip. A paint test consists of rubbing the swab tip on the paint. The paint or the swab turns pink or red to indicate a positive test for lead.

Lead Alert and E.M. Lead Test use a leaching solution in a dropper bottle and a rhodizonate indicator. The Lead Alert kit has the indicator in solution in a dropper bottle. The EM Lead Test kit has the indicator on small absorbent pads on plastic strips. The leaching solution extracts the lead from the paint and the indicator reacts with the lead in the leaching solution. The indicator turns pink or red to indicate a positive test for lead.

Both of the sodium-sulfide based test kits, Lead Detective and Acc-U-Test, are simply a five to six percent solution of sodium sulfide in a dropper bottle. A test consists of placing one or two drops of solution on the paint. The paint turns gray or black to indicate a positive test for lead.

#### Experimental Procedures

The paints prepared for this research spanned a narrow range of lead concentrations. Small increments in lead concentration provide the best definition of kit performance by reducing interpolation. Ideally, the highest number of samples are in the range where the kit results transition from positive to negative. However, the uncertainty of that

range, multiple test kits with different detection limits, and limited resources made it necessary to limit the number of samples to seven at concentrations bounding the action level. The testing performed by McKnight et al at NIST indicates that under laboratory conditions the detection limits of both chemicals fall within the range of 0% w/w to 2% w/w (7:22). This is a useful range for the testing because it encompasses the action level of 0.5% w/w and performance of the kits around this level provides the best information for screening. The target lead concentrations of the paints for this research were (in percent lead by weight) 0.06, 0.1, 0.3, 0.5, 0.7, 1.0, and 2.0.

Sample preparation. The Naval Civil Engineering Laboratory (NCEL), Port Hueneme, California, prepared the paints for this research effort. They prepared the concentrations by diluting the same original high-lead paint with the same type of non-lead paint. This controlled paint composition and ensured that each paint sample would have the same paint base and contaminants.

The paint manufacturer provided the formulations for the two original paints. Approximate concentrations of the components of concern are included in Appendix C. Due to the proprietary nature of the formulations, the exact concentrations of all components are not given. Both paints contain small amounts of cobalt, manganese, and zirconium. Titanium dioxide pigment is also found in both paints. None



of these components, at the concentrations present in these paints, should cause interference problems with any of the kits (32:784; 40).

Lead chromate is the coloring pigment contained in the leaded paint. This is a yellow pigment that is still used in some industrial paints. House paints with yellow pigments contained lead chromate in the past but it was not as common a pigment as lead carbonate (25:380). Since it was used less, lead chromate is not the ideal pigment for use in a baseline analysis such as this one. Lead chromate is also less soluble than lead carbonate and, therefore, is less available for reaction with the test chemicals (26). However, since lead chromate is still used in production and lead carbonate is not, it was the only lead paint available for preparation of the paint samples.

To compensate for the low solubility of lead chromate, the test procedures reflect some minor changes from the manufacturer's instructions. Prior to testing, the paint films were scuffed to break through any resin layer formed on top of the paint and make the lead more available for reaction. Also, up to 30 minutes were allowed with each kit for the indication of a positive test to occur. A maximum time of 30 minutes was selected because a vertical surface is not expected to stay wet with a chemical for a longer time period.

Wood was the only substrate used for the preparation of the sample paint films. A separate 12" X 12" square board was coated with each of the seven paint concentrations. Two boards were prepared at each lead concentration. Two boards were also prepared with the nonlead paint to provide a sample blank. All of the squares were covered with the same number of coats of paint and were prepared on the same days. Three coats of paint were applied to the boards to provide at least one full coat outside of the wood grain. One hour drying time was allowed between the first two coats and two days elapsed between the second and third coats. To ensure a homogeneous sample, the paints were mixed in the cans for at least five minutes by a mechanical agitator immediately before each coat was applied. After the paint films dried for several days, the squares were individually wrapped in tissue paper to prevent cross contamination.

Table 2 summarizes the lead concentrations of the dry paint films as obtained by three different methods. The target concentrations represent how NCEL mixed the paints based on the percent lead and percent solids shown on the Material Safety Data Sheets. The theoretical lead concentrations were calculated from the formulations provided by the paint manufacturer; the formulations were not available at the time the paints were mixed. Assuming that the formulations are exact, the theoretical concentrations are closest to the true lead concentrations.

Table 2. Lead Concentrations in Paint Films Based on Calculation and Analyses (all units are percent by weight)

Target Concentration	Theoretical Concentration	Lab. ICP Analysis	Lab. XRF Analysis
0.06	0.06	0.04	0.05
0.1	0.09	0.07	0.07
0.3	0.28	0.20	0.24
0.5	0.47	0.32	0.39
0.7	0.66	0.47	0.51
1.0	0.94	0.69	0.75
2.0	1.9	1.3	1.3

An independent laboratory, International Technology Corporation, analyzed the paint films using Inductively Coupled Plasma Spectroscopy; EPA Method 6010. Column 3 of Table 2 shows the results of those analyses. The report of the analytical results can be found in Appendix C. The boards were also analyzed by laboratory XRF. The XRF data in Table 2 were converted from the XRF readings using Equation (1) and assuming a film thickness of 0.005 cm and a film density of 2000 mg/cm<sup>3</sup>. Since the theoretical lead concentrations will never be known in field testing, the ICP analyses are accepted as the baseline lead concentrations of the paint films for this research.

Uncertainties are not given for the concentrations in Table 2. In the case of the theoretical concentrations, the uncertainties in paint composition could not be provided by the manufacturer. For the laboratory analyses, uncertainties could not be determined because the paint

films could not be spiked with lead in the laboratory. The XRF concentrations are based on assumptions for film thickness and density. Since the accuracy of these assumptions cannot be verified, the uncertainties in the calculations are unknown.

Test kit analysis. The evaluation of performance of the test kits began with spot testing of the sample boards with each test kit. For the spot tests, the sample boards were marked off with a 10 x 10 grid to provide 100 test sites on each board. With the exceptions of allotted time and surface scuffing, the tests were done in accordance with the instructions for surface testing included in each kit (see modified and manufacturer instructions in Appendix D). The primary exception to the manufacturer's instructions was the scuffing of the paint surface prior to each test. The kits generally recommend making an angled cut through the paint down to the substrate. The main purpose for this procedure is to expose the different layers of paint to the chemicals. Since only one paint type was applied to each square, the cutting was not necessary and the scuffing helped to compensate for the low solubility of lead chromate.

Several steps were taken to control biases that might result from the test kit user. All of the tests were conducted by one person so that procedure and user training were controlled. The boards were also randomly labeled with

letters A through G to make the tests blind with respect to the concentrations. This was intended to avoid bias from interpretation of vague results or anticipation of results at certain concentrations. However, after one set of successful tests was completed, the benefit of the random labels was lost because of user knowledge of the previous results.

Data Collection. A sample sizing plan was developed that would conserve kit materials and ensure acceptable 95% confidence interval widths for probabilities of detection. The acceptable confidence interval width was based on the maximum width that could occur with the largest number of samples taken. Because of the limited number of test kit materials and sample sites, a maximum of 30 tests were conducted with each kit at each concentration. Testing with the chemical kits is a binomial experiment because each spot test is independent and the results are either positive or negative. Therefore, the cumulative binomial distribution function was used to determine the confidence interval widths. The largest uncertainty in the probability of detection results when half the tests at a given concentration are positive and the other half are negative. Therefore, the maximum 95% confidence interval for the probability of detection with 30 samples occurs where 15 of the readings are positive and 15 are negative. With a sample size of 30, the cumulative binomial distribution

gives a maximum confidence interval width of 0.38. The maximum numbers of contradictory readings for the other sample sizes were determined so that the widths of the 95% confidence intervals did not exceed 0.38.

Table 3 presents the sample sizing plan that was developed. The sample size was increased (up to a maximum of 30) whenever the number of readings counter to the norm exceeded the determined limit. For example, if in ten samples nine are negative and one is positive, then it is necessary to increase to the next larger sample size. The same is true if nine of the ten are positive and one is negative.

Table 3. Sample Size vs. Reliability

n (Sample Size)	x (max # of results counter to the norm)
10	0
15	2
20	4
25	8
30	15

All of the test kits provide qualitative results in the form of a positive or negative detection of lead. Therefore, the samples taken at each concentration were recorded as either a plus or a minus along with the letter code of the test board. The relative intensity of the color change was noted by multiple pluses for each positive

result. The time required for the color change to occur was also recorded.

#### Expected Results

From the data, a probability of detecting lead can be calculated for each kit at each concentration. The probability of detection is equal to the number of positive readings divided by the total number of samples. This is also the reliability of the kit to provide a positive reading at that concentration. The cumulative binomial distribution function determines the width of the 95% confidence interval for this statistic. With this information, the probability of detection is plotted against lead concentration. The resulting plot defines the performance curve for each kit (41). Based on the performance curve, an estimate is made of the concentration above which there is at least a 95% probability of a positive reading. This concentration is the detection level as defined in this research.

Comparison of Results. Performance and the effects of false positive and false negative readings can be compared in terms of a discomfort curve (18). Figure 4 is an example of a discomfort curve that might be used for lead paint abatement. The curve represents the willingness that a decision maker might have to accept the two types of error. In this case, accepting a false positive results in a waste

of money by the needless removal of paint that is not a hazard. Accepting a false negative creates a possible health hazard by allowing leaded paint to remain unmanaged.

Figure 4 shows how the acceptable rates of error might change depending on the lead concentration and the type of error involved. Between 0.4% w/w and 0.5% w/w of lead the decision maker is willing to accept 100% false positive because he/she is indifferent to whether or not the paint is removed. The decision maker in this example accepts a 10% false positive rate with a concentration between 0.18% and 0.4% w/w and a 5% false positive rate with a concentration of lead less than 0.18% w/w. Because of the possible health effects, the acceptable false negative rate is lower than the acceptable false positive rate. An acceptable false

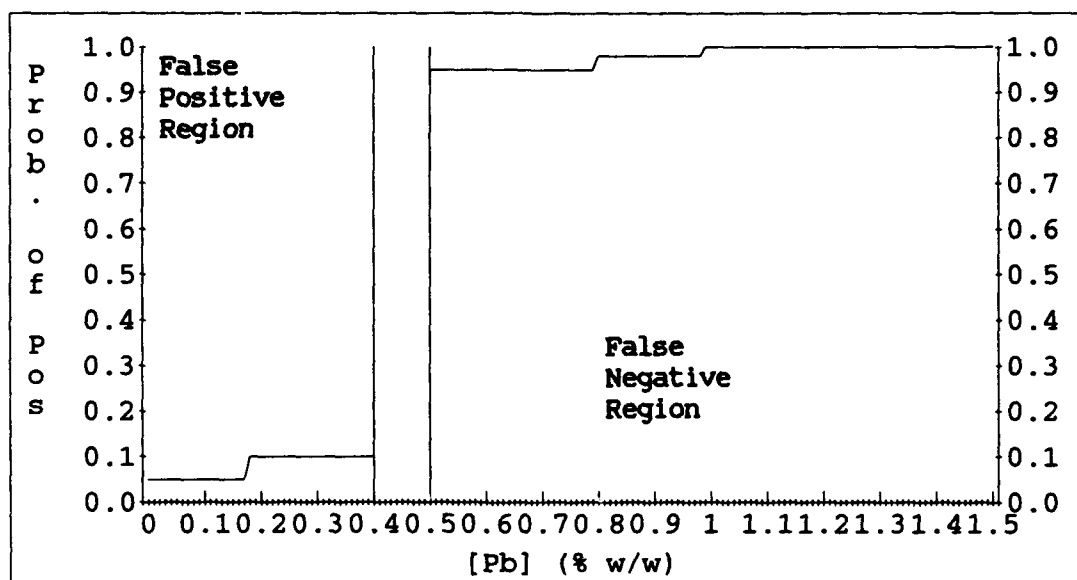


Figure 4. Sample Discomfort Curve for Lead Paint Abatement (18)



negative rate of 5% might be chosen at concentrations between 0.5% and 0.8% w/w, a 2% false negative rate at concentrations between 0.8% and 1.0% w/w, and no false negatives would be accepted at concentrations greater than 1.0% w/w.

The performances of the kits are compared by overlaying the performance curves with the discomfort curve. The dashed line added to the sample discomfort curve in Figure 5 shows what the optimum performance curve for a test kit would be for this example (18). A test kit is the most useful to the decision maker if the transition from reliable positive readings to reliable negative readings occurs in the region of indifference. The slope of the curve changes

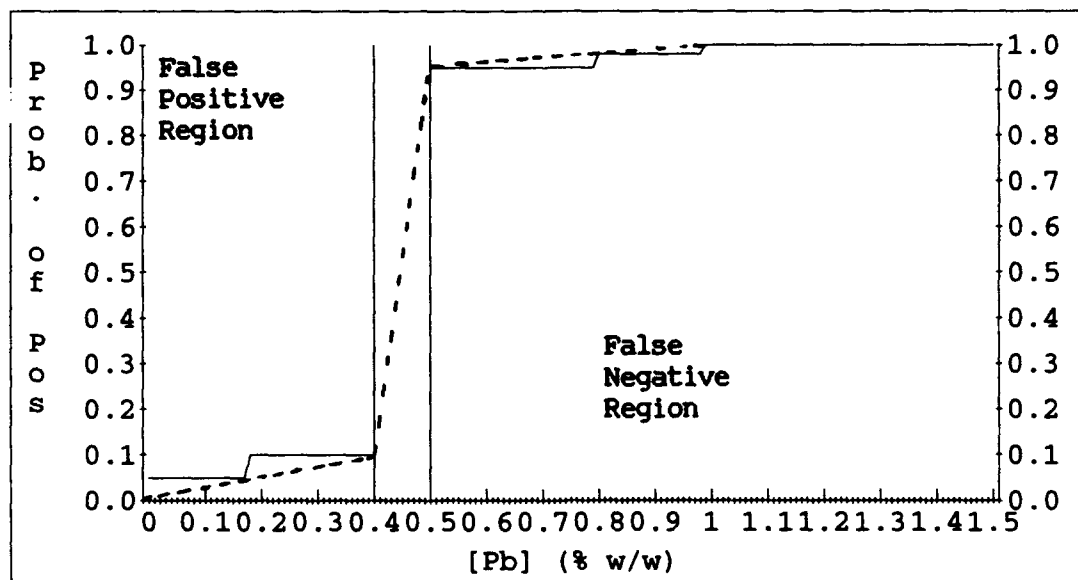


Figure 5. Optimum Performance Curve Overlaid by Sample Discomfort Curve (18)

where false positive and/or false negative readings become unacceptable to some degree. The optimum performance curve never crosses the acceptable probabilities of false positive and negative readings. The discomfort curve and optimum performance curve serve as a fixed comparison for the performance curves obtained for each test kit.

### Summary

This research provides information on the performance of five lead paint test kits by evaluating them on common basis. It recommends standard testing and reporting procedures so that results of future tests can be compared. The test procedures control variables that might affect lead detection so that a baseline performance is obtained. Testing each kit on the same material under the same conditions allows an equitable assessment to be made of their relative performances. The elimination of field variables in the laboratory setting limits the extent to which the results can be generalized. However, the research provides a basis of performance for the purpose of comparison.

#### IV. Findings and Analysis

##### Presentation of Data

The five test kits selected for this study were used on the sample paint boards and the positive and negative readings were recorded. Table 4 presents a compilation of the results. The table shows the total number of tests conducted, the number of positive readings, and whether the readings were acceptable (Ok), falsely positive (FP), or falsely negative (FN). An acceptable reading is a positive reading at a lead concentration greater than 0.5% w/w or a negative reading at a lead concentration less than 0.5% w/w. For this research, a positive reading at 0.47% w/w is also counted as an acceptable reading because that concentration is within the region of indifference on the sample discomfort curve. There are two sets of data for the LeadCheck tests because two test runs were completed.

Acc-U-Test and Lead Detective, sodium-sulfide-based test kits (identified in Table 4 as SS), gave all positive readings regardless of lead concentration. Each test consisted of placing one drop of solution in ten squares on each test board. The paint turning gray or black indicated a positive test for lead (see the instructions in Appendix D). The resulting color for all lead concentrations was essentially the same dark gray color. The Acc-U-Test solution was used to test the blank sample that was coated

Table 4. Results of Spot Tests on Lead-Based Paints

Kit Brand	Chemical*	Lead Conc. (% w/w)	# of Tests	# of Positives	False + or False - **
Acc-U-Test	SS	1.3	10	10	10 Ok
		0.69	10	10	10 Ok
		0.47	10	10	10 Ok
		0.32	10	10	10 FP
		0.20	10	10	10 FP
		0.07	10	10	10 FP
		0.04	10	10	10 FP
		0.0	10	10	10 FP
Lead Detective	SS	1.3	10	10	10 Ok
		0.69	10	10	10 Ok
		0.47	10	10	10 Ok
		0.32	10	10	10 FP
		0.20	10	10	10 FP
		0.07	10	10	10 FP
		0.04	10	10	10 FP
LeadCheck	SR	1.3	10/10***	10/10	10 Ok/10 Ok
		0.69	20/9	16/9	4 FN/9 Ok
		0.47	10/15	10/15	10 Ok/10 Ok
		0.32	25/20	17/20	17 FP/20 FP
		0.20	10/20	0/16	10 Ok/16 FP
		0.07	10/10	0/0	10 Ok/10 Ok
		0.04	10/10	0/0	10 Ok/10 Ok
Lead Alert	SR	1.3	10	0	10 FN
EM Lead Test	SR	1.3	10	0	10 FN
<p>* SS - Sodium Sulfide SR - Sodium Rhodizonate</p> <p>** Ok - Acceptable Reading FP - False Positive FN - False Negative</p> <p>*** Two sets of tests were run with LeadCheck. Data represent 1st run/2nd run.</p>					

with non-lead paint. That test also resulted in ten positive readings out of ten samples. False positive readings on the blank sample imply that the false positive readings at the low lead concentrations were not merely highly sensitive reactions with the small amounts of lead present.

Lead Alert and EM Lead Test, sodium-rhodizonate-based test kits (identified in Table 4 as SR), both failed to detect lead in any of the tests at 1.3% w/w. Each test consisted of placing two drops of leaching solution in ten squares on the test board and allowing it to stand for 30 minutes. The solutions on the board were then checked with the indicators. The indicator turning pink or red indicated a positive test for lead (see instructions in Appendix D). Neither kit produced a color change at the 1.3% w/w concentration. Because of the failure at the high lead concentration, no further tests were conducted with these two kits.

LeadCheck, also a sodium-rhodizonate-based test kit, was the only kit tested that provided the type of response that was anticipated from all of the kits at the onset of the study. The numbers of positive and negative readings varied depending on the lead concentration. Each test consisted of rubbing one swab on a test square for 30 seconds; a different swab was used for each test square. The paint or the swab turning pink or red indicated a

positive test for lead (see instructions in Appendix D). A maximum of 30 minutes was allowed for the color change to occur. Any color change which occurred after 30 minutes was still counted as a negative result.

Two separate rounds of sampling were conducted with LeadCheck. For the first sampling run, the number of samples was adjusted in accordance with the sampling scheme shown by Table 3 in Section III. Sampling space was still available on the test sheets and some LeadCheck swabs remained after the first run was completed. Therefore, additional tests were conducted with LeadCheck to reduce the width of the 95% confidence intervals on the probabilities of detection. The numbers in Table 4 report the results of the first run followed, to the right of the slashes, by the results of the second run.

#### Discussion of Problems

The testing resulted in several problems and unexpected findings. Some of the problems relate to the kits themselves and others relate to controlling variables such as user training, true blind concentrations, and subjective determinations.

Acc-U-Test and Lead Detective. Obtaining 100% false positive readings below 0.47% w/w with the sodium sulfide solutions was unexpected. Based on the formulation of the paint, no interferences were anticipated (32:784). The

manufacturer of the Acc-U-Test kit was consulted to obtain a possible explanation for the false positive readings (39). The test results were explained to the manufacturer representative. He identified the results as what would be expected from a positive test for lead and proposed that the paint samples must have been contaminated. Lead contamination of the sample boards is unlikely since the paint samples collected for laboratory analyses were collected after the sodium sulfide tests were run. Therefore, if the false positive readings with sodium sulfide had been caused by contamination of the sample boards, the laboratory results would have shown higher levels of lead than expected. The laboratory analyses did not detect lead in the non-lead paint and lead concentrations were actually lower than anticipated for the other paints. This rules out contamination of the test boards as an explanation for the false positive readings.

As mentioned in Section II, the manufacturer of Lead Detective warns of a possible interference from titanium dioxide; titanium dioxide is the primary pigment in the non-lead paint. The manufacturer states that "there may be a light gray color formed" (19:16). Shades of color are very subjective determinations to make. However, the color changes of the paints in this study would probably all be interpreted as dark gray. The manufacturer of Acc-U-Test conducted actual tests on solid titanium dioxide and

reported no color change (40). Based on the Acc-U-Test manufacturer's results, it is unlikely that titanium dioxide was the cause of the false positive readings.

Dr. Mary McKnight of NIST was also consulted for a possible explanation of the false positive readings (26). She identified cobalt, a common drier in oil-based paints, as the most likely interference. The laboratory analyses of the paints show the cobalt concentration to be consistently around 0.045% w/w (see Appendix C). Cobalt at that concentration would not normally be expected to produce false positive readings (32:784). McKnight, however, states that the interference has been noted before under laboratory conditions (26).

Lead Alert and EM Lead Test. No lead was detected by either the Lead Alert or the EM Lead Test kit at the highest lead concentration of 1.3% w/w. Therefore, no further tests were conducted with these two kits. A longer leaching time or a more soluble lead pigment might make the lead detectable by these two kits. However, an extended leaching time requires removal of a paint sample from a vertical surface to keep the paint in contact with the leaching solution. There is also, at this point, no way of knowing how long of a leach time is sufficient. Obtaining such information will require a separate study of the kits using various leach times. Extensive leaching procedures are also



undesirable for an easy-to-use field test kit for civil engineering work crews.

LeadCheck. The second round of tests with the LeadCheck kit showed an improvement in sensitivity from the first round. Most of the improvement was probably due to the tester being more familiar with the use of the kit and the interpretation of results. The time required for the color change with LeadCheck seemed to vary both with lead concentration and amount of reagent left on the surface. The color change occurred as the solution dried, therefore, some of the faster times came from the spots with the least solution. The tester realized this and adjusted his procedure accordingly. This illustrates the difficulty in maintaining constant user training and procedure even with one tester.

The instructions for data collection required that the intensity of the color change be designated by the number of "+" signs recorded. However, the information on the data sheets is not indicative of the actual results of color intensity. When the first tests were made, there was nothing available for comparison of relative shades. Some patches also darkened within the 30 minute time frame. No attempt was made in either case to go back and adjust the information on the data sheets. Use of a visual color scale may improve the determination of color intensity.

### Statistical Analysis

Only the LeadCheck test kit provided data that could be used for a statistical analysis of the performance of the kit. A probability of detection was calculated for each lead concentration,. Figures 6 - 8 show the calculated probabilities of detection and the curves fit to them. The concentrations shown are those that were obtained from the laboratory ICP analyses in percent by weight. Figures 6 and 7 show the results of the first and second test runs, respectively. The positions and shapes of the curves in these two figures clearly show how the performance changed from the first run to the second. The concentration for 95% probability of detection is about 0.44% w/w on Figure 6 and about 0.23% w/w on Figure 7. This represents nearly a 50% increase in the sensitivity level between the two runs. The slope of the transition is also much steeper in Figure 7 than in Figure 6 indicating that a trained user can obtain a more precise cutoff between detected and non-detected concentrations. To take advantage of all the data and estimate the overall performance of the kit, Figure 8 combines the data from the two runs. Figure 8 represents what might be expected as an average response when both trained and untrained individuals performing tests. The following describes how these graphs were obtained.

Binomial Experiments. To better understand the probabilities of detection and their confidence intervals,

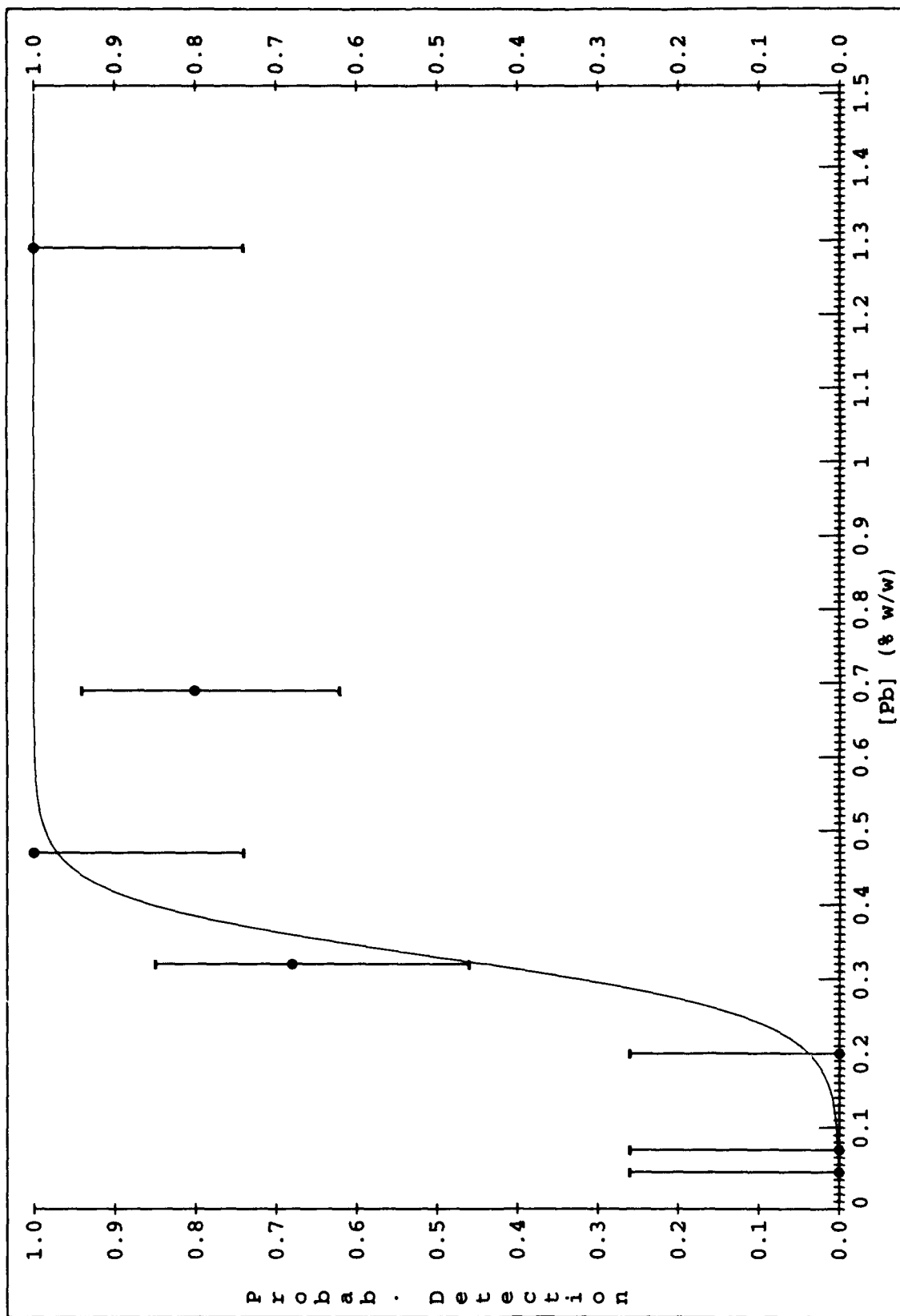


Figure 6. LeadCheck Detection Probability vs. Lead Concentration (Based on 1st Run)

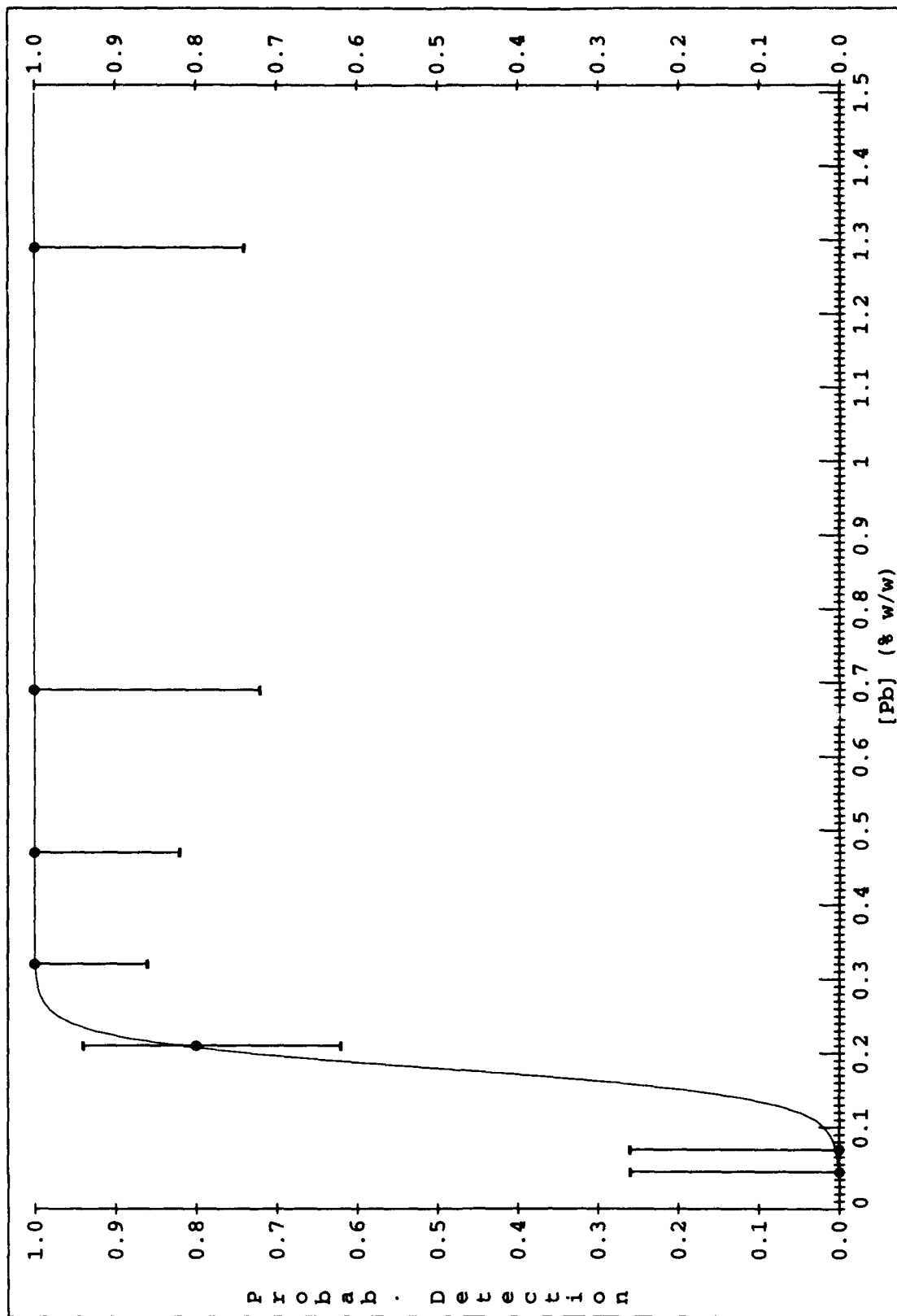


Figure 7. LeadCheck Detection Probability vs. Lead Concentration (Based on 2nd Run)

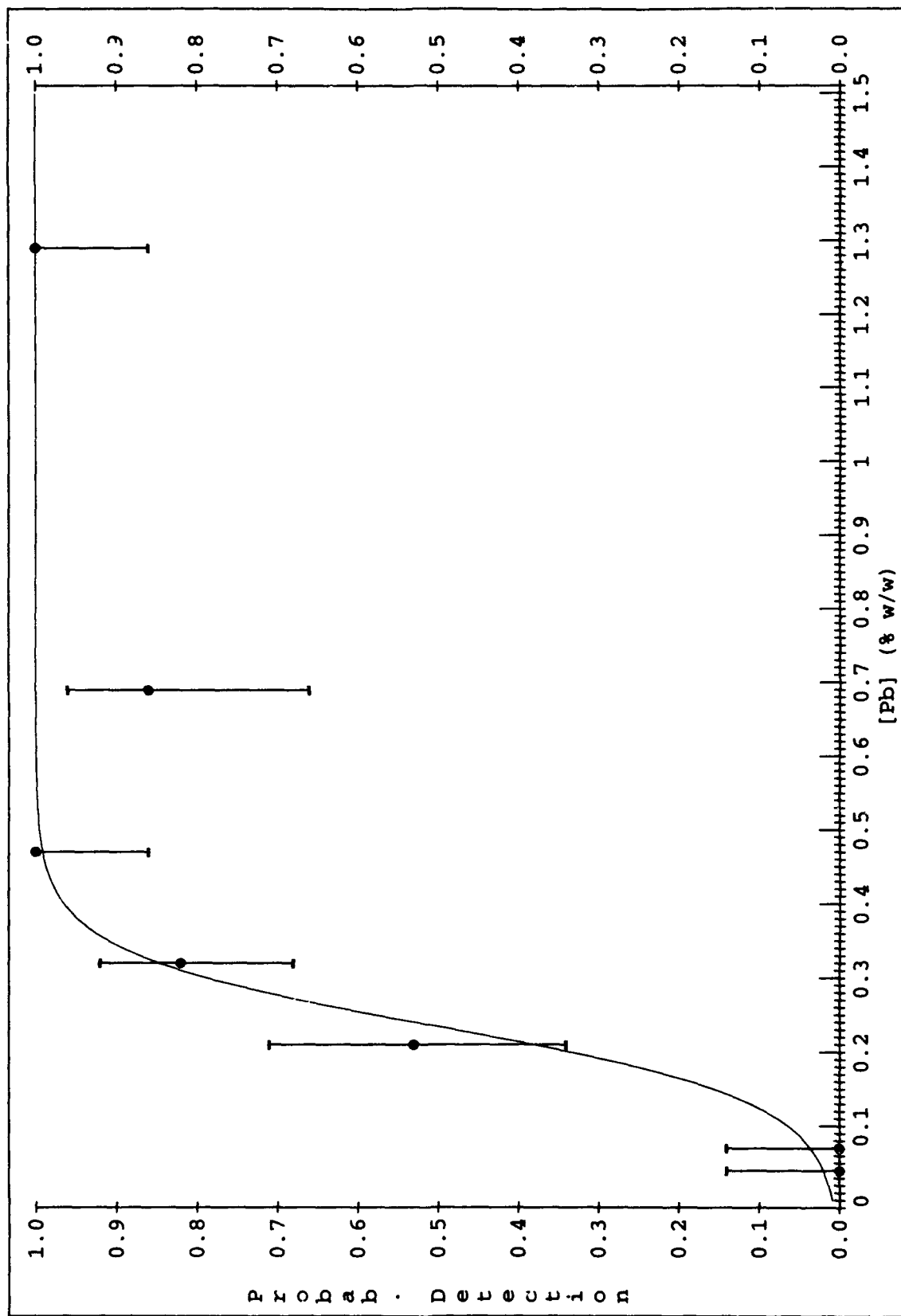


Figure 8. LeadCheck Detection Probability vs. Lead Concentration (Based on Total Tests)

it is important to first have a knowledge of binomial distributions. A binomial experiment consists of any number of identical, independent trials where each trial can result in one of two possible outcomes (15:104). The probability of having a given number of one outcome from a given number of trials is obtained from the binomial distribution function:

$$P(X = x) = b(x; n, p) = \frac{n!}{x! (n - x)!} p^x (1 - p)^{n-x} \quad (2)$$

where  $P$  is probability,  $X$  is a binomial random variable,  $x$  is number of successes,  $b$  is the binomial probability function,  $n$  is number of trials, and  $p$  is probability of success (15:107). The probability of having less than a given number of successes from a given number of trials is obtained from the cumulative binomial distribution function (15:108):

$$P(X \leq x) = \sum_{0}^x b(x; n, p) \quad (3)$$

The testing conducted in this research effort is a binomial experiment since each test is identical and independent and the results are either positive or negative. The probability of detection calculated with the data from this research is the value for  $p$  in Equations (2) and (3).

Probability of Detection. At each lead concentration, the number of positive tests was divided by the total number

of tests to give the probability of detection at that concentration. This was done for both test rounds individually and for the combined data. Next, the 95% confidence intervals for the probabilities of detection were determined. Equation (3) was used to determine the confidence intervals. The endpoints of the confidence intervals were found by substituting the number of tests,  $n$ , and the number of positive readings,  $x$ , at each concentration into Equation (3) and solving for  $p$ . The upper limit of the confidence interval represents the detection probability,  $p$ , required so that  $P(X \leq x) = 0.025$  (0.025 is half of the 5% probability excluded from the 95% confidence interval). The lower limit of the confidence interval represents the detection probability,  $p$ , required so that  $P(X \geq x) = 0.025$  which is the same as  $P(X \leq x-1) = 0.975$ . Figures 6 - 8 show the 95% confidence intervals as vertical lines passing through the calculated probabilities of detection (represented by the points).

Curve Fit. A curve was fit through the experimental probabilities of detection to interpolate between the seven concentrations tested and provide the performance curves for the test kit. A sigmoidal curve was used to fit the data because of the known limits on probability of detection at zero and one and the transition region in between. The

following form of equation is known to fit a sigmoidal curve (34):

$$dP/dC = R P (1 - P/K) \quad (4)$$

where  $P$  is the probability,  $C$  is the concentration,  $R$  is a constant related to the specific data, and  $K$  is a constant equal to the maximum value that  $P$  can attain (1 in this case). Setting  $K$  equal to 1, Equation (4) can be solved and rearranged to give

$$P = \frac{B}{e^{-R C} + B} \quad (5)$$

where  $B$  is the constant of integration. A value for  $B$  was then found by defining a concentration,  $C^*$ , as the concentration when  $P$  equals 0.5. Substituting the derived value for  $B$  into Equation (5) gives

$$P = \frac{e^{-R C^*}}{e^{-R C} + e^{-R C^*}} \quad (6)$$

Iterations of  $R$  and  $C^*$  in Equation (6) were used to fit the curves to the data in Figures 6 - 8. In Figure 6,  $R = 25$  and  $C^* = 0.33$ , in Figure 7,  $R = 50$  and  $C^* = 0.18$ , and in Figure 8,  $R = 20$  and  $C^* = 0.23$ .

Since it is representative of the overall performance of the kit, the curve shown in Figure 8 is used to represent the baseline performance curve for the LeadCheck test kit.



Detection Level. The detection level of a kit is the lead concentration at which the kit will reliably identify the presence of lead in paint. For this research, the detection level is defined as the lead concentration above which there is at least a 95% probability of detection. In other words, if the lead concentration of a paint is at the detection level, 95% of the spot tests performed will result in a positive reading. Using the graph in Figure 8 for interpolation of the data gives a detection level for LeadCheck of approximately 0.38% w/w. This means that there is at least a 95% probability of obtaining a positive reading given a lead concentration of 0.38% w/w or higher. This is not the same as saying that there is a 95% probability that the concentration is at or above 0.38% w/w given a positive reading.

It is important to remember that this value relates to the controlled conditions under which this study was conducted and is expected to be the best-case value. Field variables such as paint composition, paint age, layered combinations of paints, type of substrate, and user training will affect the actual detection level. Most of these variables, with the exception of improved user training, will probably tend to shift the detection level to a higher concentration.

### Comparison of Performance

The significance of the performance curves and probabilities of detection is best understood by comparing the performance curves to the discomfort curve. Figures 9 - 11 overlay the performance curves for the kits on the sample discomfort curve presented in Section III.

Figure 9 presents the performance of the LeadCheck kit as compared to the sample discomfort curve. This figure shows that the performance never enters the region where false negatives are unacceptable. Therefore, the kit functions better than required as a negative screen. In other words, a negative reading can be accepted as an indication that a paint is not lead based. However, the kit has a detection level that is lower than the optimum, 0.38% w/w instead of 0.5% w/w, which results in a high rate of false positives. This rate of false positive readings would be unacceptable by the standards of this sample discomfort curve and a positive reading would give insufficient information about the need to take corrective action. However, under different needs from the decision maker, the discomfort curve would change and the false positive rate could be acceptable. Therefore, since the readings with LeadCheck change depending on lead concentration, useful information can be obtained by using this kit.

Figure 10 represents the failure of the Acc-U-Test and Lead Detective test kits as seen in this research. The performance curve is a straight line at 100% probability of detection. These kits show no possibility of a false negative because no negative readings were obtained. Therefore, no health hazard would be created by relying on the results of these test kits because the paint in all housing units would be removed. However, the percentage of readings in the false positive region is unacceptable because of the money that would be wasted by removing all of the paint that tests positive for lead. Based on the results of this research, Acc-U-Test and Lead Detective do not provide information that would assist in deciding whether or not to remove paint from a facility.

Figure 11 presents the performance of Lead Alert and EM Lead test as a straight line at 0% probability of detection. This signifies that under the conditions of this research the detection level of the kits lies above 1.3 % w/w. Comparing these results to the discomfort curve shows an unacceptable performance in the false negative region; all readings were falsely negative. Therefore, a health hazard would be created by relying on the results of these test kits because leaded paint would be left in place. Since there are no positive readings, there are no readings that exceed the acceptable false positive limit. For these two

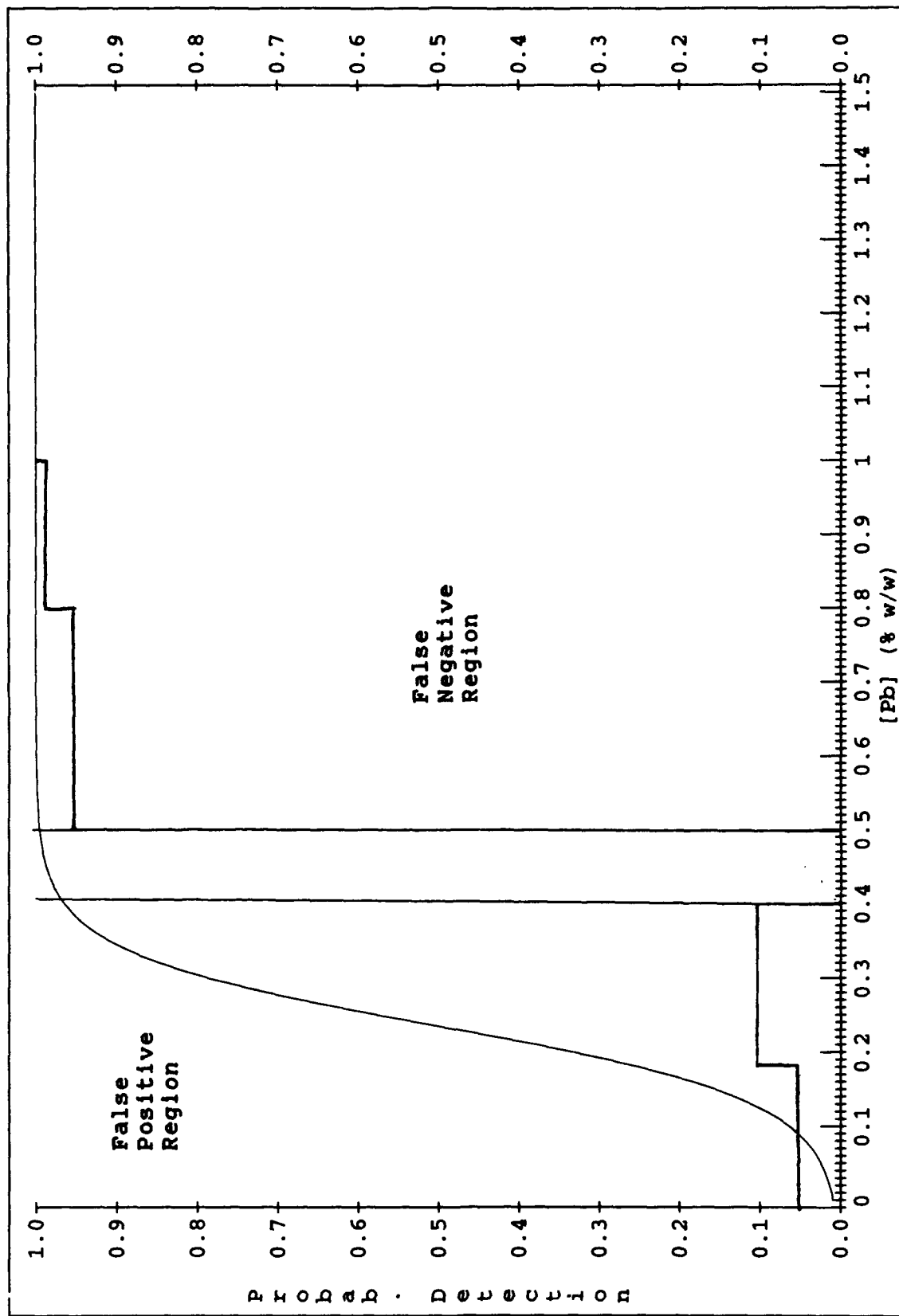


Figure 9. LeadCheck Performance Curve with Discomfort Curve

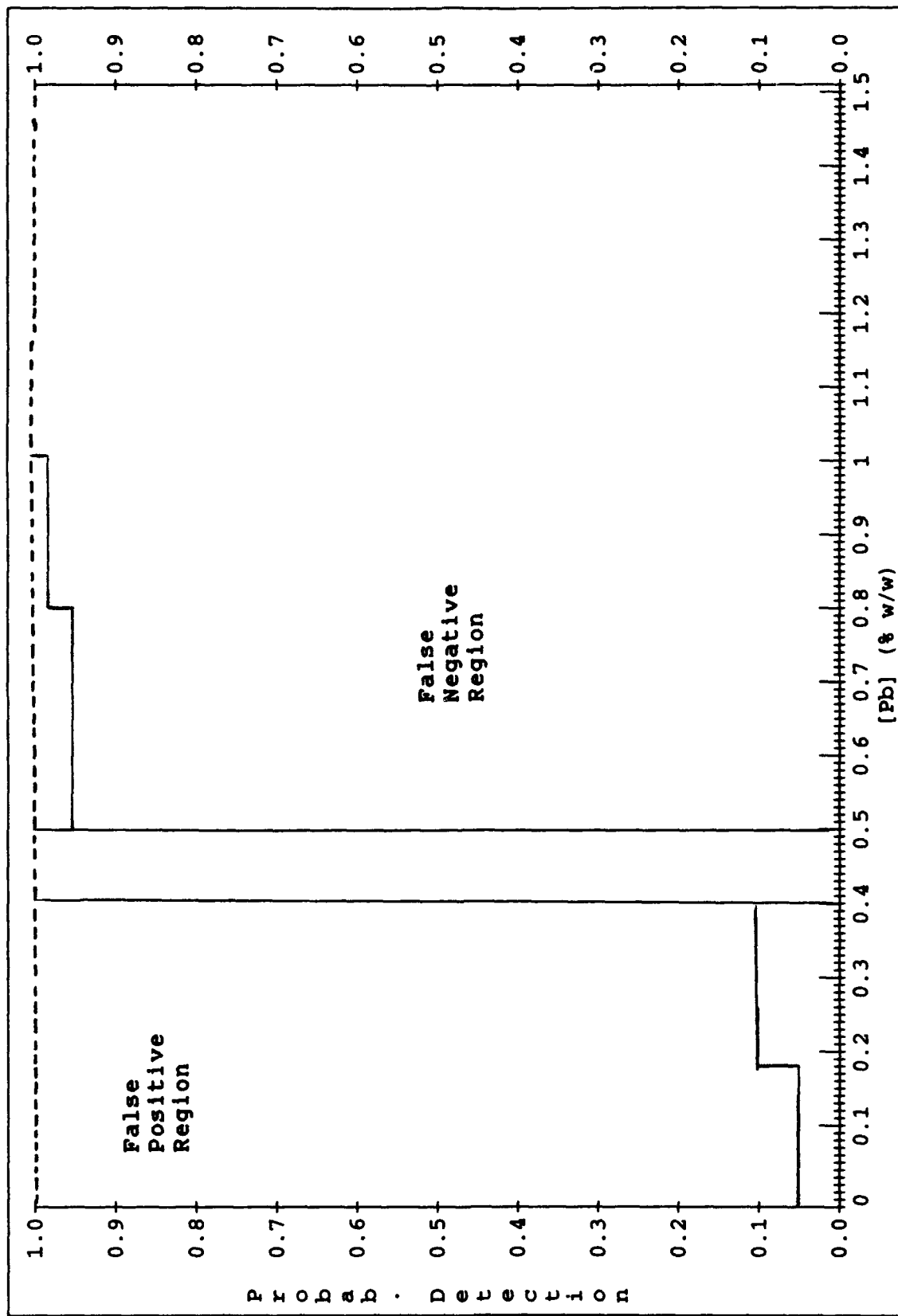


Figure 10. Acc-U-Test and Lead Detective False Positive Performance with Discomfort Curve

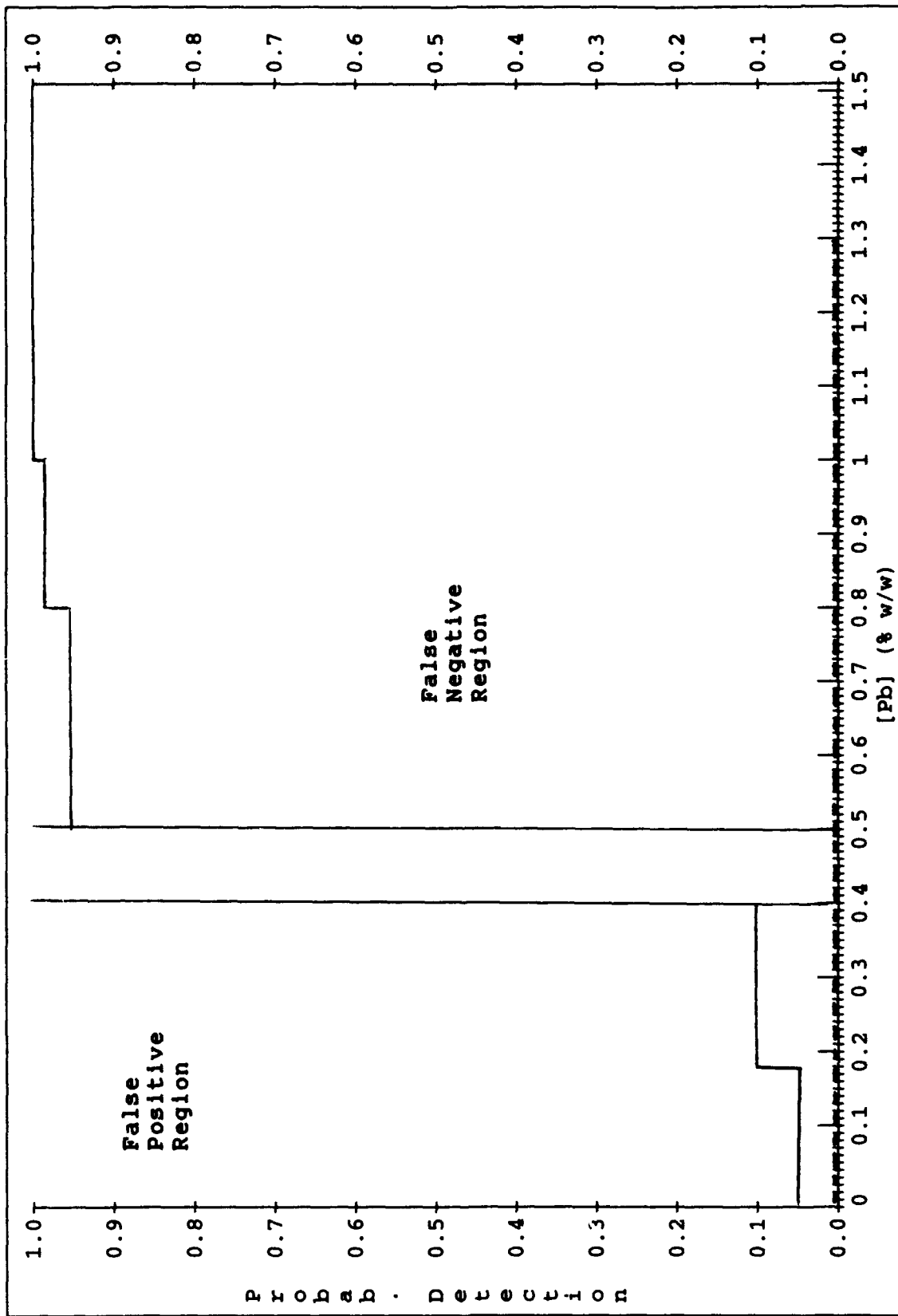


Figure 11. Lead Alert and Lead Test False Negative Performance with Discomfort Curve

kits, a positive reading indicates that the paint is hazardous but a negative reading provides no information.

#### Field Sampling

The detection level and rate of false positives for LeadCheck can be improved relative to the sample discomfort curve by taking more samples at a site and redefining a positive detection. For example, a positive detection could be defined as three positive readings out of three tests. The new probabilities of detection are then calculated using Equation (3) with the original probabilities of detection providing the values of  $p$ . Figure 12 illustrates this for the LeadCheck kit. The solid performance curve represents the probability of one positive reading from one test which is the same as the baseline performance curve in Figure 8. The dashed performance curve represents the probability of three positive readings from three tests. This new definition of positive detection has the effect of shifting and bending the curve to the right. The number of false negatives is still acceptable and the number of false positives has improved. This curve shift will continue with increasing numbers of tests. The performance curve achieves the optimum detection level, 0.5% w/w, when positive detection is defined as ten positive readings out of ten tests. Therefore, defining a positive test for lead as all positive readings from multiple samples of the same surface

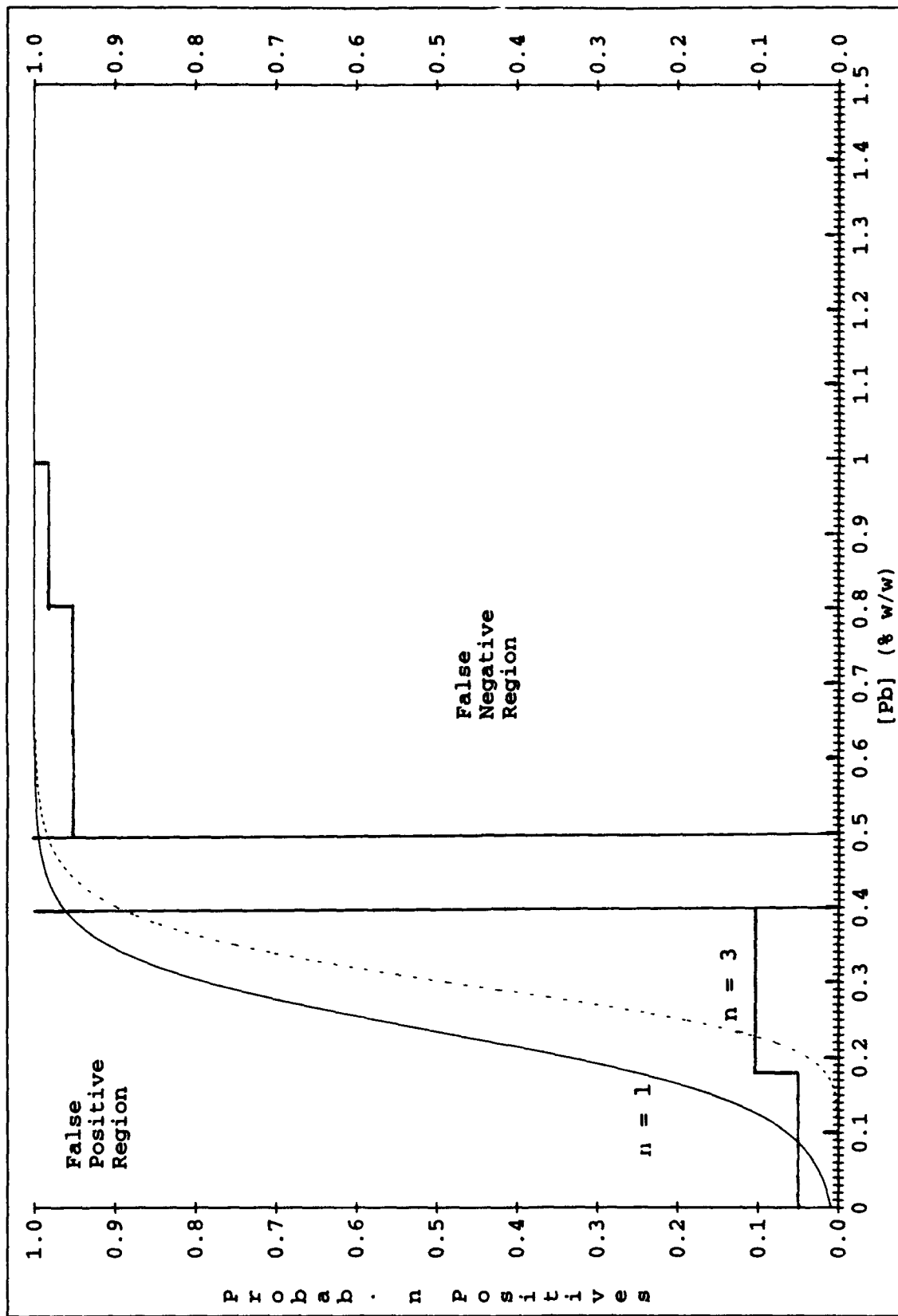


Figure 12. LeadCheck Performance Curves with  $n = 1$  and  $n = 3$



will reduce the number of housing units are needlessly remediated. The cost of sampling increases with multiple tests but is insignificant when compared to the cost of paint remediation.

### Summary

Four of the five chemical spot test kits selected for this research gave results that could not be statistically analyzed. The Acc-U-Test and Lead Detective kits gave 100% positive readings at all lead concentrations and the Lead Alert and EM Lead Test kits resulted in 100% negative readings at the highest lead concentration of 1.3% w/w. The problem with the sodium sulfide kits was probably caused by a chemical interference with the paint. The negative readings on the sodium rhodizonate kits indicate that the highest lead concentration was below the detection limit of those kits under the conditions of this research.

The LeadCheck kit gave results similar to what was expected from all of the kits. The best estimate for the detection level of LeadCheck, under the controlled conditions of this research, is 0.38% w/w with a 95% probability of detection. Comparison of the LeadCheck kit to the discomfort curve shows that it serves as a good negative screening tool but the level of false positives below 0.4% w/w is unacceptable.

## V. Conclusions

### Thesis Summary

Lead-based paint remains one of the significant sources of lead for lead poisoning of humans today. The extent of the problem in the Air Force is just beginning to be evaluated. The Air Force can expect to find lead-based paint in all industrial facilities and in a large percentage of non-industrial facilities built before 1980. Probably about 105,000 Air Force housing units have lead-based paint on at least one painted surface. All bases are required to conduct testing to evaluate the extent of the problem but initially only a fraction of the facilities will actually be tested. Work crews that are performing sanding, cutting, or demolition work on a painted surface need to know the possible lead hazard at each site before they begin work. In order to protect themselves and building occupants from the hazards of exposure to lead-based paint, civil engineering work crews need a quick and accurate means of screening for the presence of lead. Chemical test kits are available and have the potential to provide such a screen for lead in paint. The purpose of this research was to assess the baseline performance of these chemical spot test kits and provide a standard evaluation procedure for follow-on research.

AFCESA requested that the research be completed to help make a recommendation on the use of chemical test kits by Civil Engineering. To make such a recommendation, information on the detection level and reliability of the kits needs to be available. The performance of the kits is influenced by variables such as paint composition, paint age, layered combinations of paints, type of substrate, and user training. The procedure in this research eliminated all other variables except kit brand and lead concentration to determine a baseline detection level and performance for each kit.

The performance of the kits was evaluated around an action level of 0.5% w/w to try to identify which kit provides the best information about the potential lead hazard. The concentrations ranged from 0.04% w/w to 1.3% w/w. Several previous studies showed that this range of concentrations should also include the detection limits of the kits. Two sodium sulfide kits, Acc-U-Test and Lead Detective, had an unacceptable rate of false positive readings. In the testing all readings from these two kits were positive regardless of the lead concentration. On the other end of the spectrum, the lead concentrations were below the detection limits of two sodium rhodizonate kits, Lead Alert and EM Lead Test, as no positive readings were obtained from them. LeadCheck, also a sodium rhodizonate kit, provided positive and negative readings that varied

with concentration as expected. For this kit, probabilities of detection were calculated and a performance curve was generated and compared to a sample discomfort curve. The detection level at 95% probability of detection that was determined for LeadCheck is 0.38% w/w. Comparison to the discomfort curve highlighted the fact that the kit provides useful information with a negative reading but may have a high rate of false positives. The acceptability of the false positives depends on the needs of the decision maker when setting up the discomfort curve. Since the readings with LeadCheck do change depending on lead concentration, useful information can be obtained by using this kit.

All of the results from this study are valid for the controlled conditions and paint makeup used. The test procedures purposely eliminated variables that may influence kit performance so that a baseline performance could be established. All of the variables encountered in the field except increased user training will tend to degrade the kits' performance by shifting the detection level to a higher concentration.

#### Evaluation of Success

This research effort establishes a sound standard for evaluation of lead-based paint test kits and reporting of the results. All previous research on the test kits was performed independently with different conditions, kits,

units of measure for lead concentration, methods of sampling, and means of reporting. The data from the previous tests are difficult to compare to each other to draw a conclusion about the performance of the kits. The methodical approach presented here will allow one study to build upon another to reach a determination of overall performance and reliability.

Reporting the data as a performance curve and comparing it to a discomfort curve facilitates an understanding of the results. Other study reports have been ambiguous on biases from extreme concentrations and meanings of reported probabilities.

The problems encountered in this testing illustrate how easily the results of the test kits can be affected. The composition of the paint used undoubtedly hampered the performance of the four test kits that failed. However, the paint is indicative of a paint that can be found in field testing and therefore provides information on potential problems with the kits. Additional testing in the laboratory and in the field is required before the overall performance of these kits can be determined.

#### Field Use of Kits

Testing with the kits is relatively inexpensive and can provide a significant cost savings to the Air Force. Both types of chemical test kits are currently being used in

field testing with XRF and laboratory backup. The Air Force policy on lead-based paints allows for the use of chemical test kits. These kits may provide installations with significant cost savings from paint sampling. LeadCheck is the most expensive of the kits because of the all-in-one swab packaging and costs about \$1.35 per test. Compare this to \$35 per test for laboratory testing and \$20,000 to purchase a portable spectrum-analyzer XRF. Based only on the cost of equipment, it will require almost 15,000 tests before the cost of testing with the purchased XRF is down to \$1.35 per test.

HUD estimated that the average cost of testing a housing unit with XRF and laboratory analysis is about \$375 (8:4.4). For a conservative estimate, assume that only the housing units with high lead concentrations can be identified with chemical spot tests and some laboratory backup. Based on the age distribution of Air Force housing in Figure 3 and the HUD data in Figure 2, the Air Force has nearly 48,000 housing units with lead concentrations over 2 mg/cm<sup>2</sup>. At \$375 per unit these will cost the Air Force almost \$18 million just to test. Assuming an average of 6 rooms per unit with ten spot tests and one laboratory analysis per room, the testing would cost about \$14 million. This provides a savings of \$4 million to the Air Force.

As more information about kit performance is obtained, it may become possible to use two test kits in tandem to

improve the information obtained from the kits. A sensitive kit whose detection level is below 0.5% w/w provides assurance with a negative reading that the surface is safe but positive readings can occur above or below the action level. A less sensitive kit with a detection level above 0.5% w/w provides a warning with positive readings of unsafe lead concentrations but negative readings are inconclusive. A surface that has a negative reading with the less sensitive kit would be retested with the sensitive kit. If the second reading was positive, the concentration would be narrowed down to the range between the two detection limits. If the second reading was also negative, the surface could be declared safe to work with. This type of dual testing will increase the cost slightly but it is still less expensive than laboratory analysis and may provide better information than an XRF test.

## VI. Recommendations

### Test Kit Analysis

It is tempting to seek a final answer all at once by conducting massive field testing of the kits. However, this will inevitably result in confusion. This research lays out a methodical approach for continued testing of lead-based paint test kits. Additional laboratory testing should be accomplished with carefully controlled variables so that the affect of each can be evaluated. The testing should be coordinated with other government agencies who are working with the issue such as HUD, NIST, EPA, and CPSC.

The Air Force has the opportunity to obtain field data while other testing is being conducted. Installations that are using chemical spot tests in conjunction with laboratory analysis should be required to keep records of the results. A data base could be built at Brooks AFB to compile data such as type of kit, kit reading, lead % w/w, age of facility, and location of sample. The data should be limited to samples that were verified by laboratory testing and not XRF because the validity of XRF data will always be in question. Laboratories have standard methods and quality control measures that are followed but the quality of the procedures of the XRF tester will not be known. The quality control during sampling and shipping will be unknown but sample contamination will hopefully be minimal.



### Recommended Changes

Because of the interferences encountered in this testing, new paints should be prepared for any future tests. The formulation of the new paint should be compared to what was used here so that materials of concern, particularly cobalt, can be avoided. A survey of old paint storage areas around the Air Force may locate some pre-1977 lead-based paint that could be used for sample preparation.

As resources allow, the new paint samples should be prepared with more concentrations and across a wider range. More data points will provide a better definition of the performance curves. The smallest increments in concentration should be around the detection levels of the kits. However, if the detection levels are spread out, this may not be possible. Extending the concentration range up to 3% or 4% w/w should capture the detection levels of the Lead Alert and EM Lead Test kits.

To maintain a blind sample concentration, it will be necessary to prepare separate sample sheets for each kit. Using the same board for different kits decreased the blindness of the concentrations after one successful set of tests had been run with LeadCheck because the previous result could be seen.

If intensity of color is going to be recorded, a visual color chart should be prepared prior to testing. Various

shades of pink to red and gray to black could be assigned a number that would be recorded with a positive result.

Probably only extreme shades of color such as light pink and red or light gray and black will be useful in the field.

Requiring someone to distinguish shades in between is too subjective to be included in an operating procedure.

## Appendix A: Definition of Terms

**Abatement.** Action taken to remove, enclose, or otherwise reduce or eliminate a hazard.

**Action Level.** A concentration that is selected as a likely threshold at which health or safety hazards become significant. This is the level at which corrective or protective action must be taken.

**Binomial Experiment.** An experiment consisting of any number of identical, independent trials where each trial can result in one of the same two possible outcomes (15:104).

**Detection Level.** The concentration at which a given method of analysis will reliably identify the presence of the substance being tested for. Sometimes referred to as sensitivity.

**Extraction.** A process by which one (or more) component is removed from a mixture. In the case of lead extraction from paint, the lead is leached from the paint film by an acidic solution.

**False Negative.** A test result which indicates the absence of a substance, or presence below a level of concern, when the substance is actually present or is present above the level of concern.

**False Positive.** A test result which indicates the presence of a substance, or presence above a level of concern, when the substance is actually not present or is present below the level of concern.

***in-situ.*** A test conducted in place without removing the substance being tested from its current environment.

**Lead-Based Paint.** Any paint in which the lead concentration exceeds the regulatory limit. For a newly manufactured paint, it is any lead concentration greater than 0.06% by weight. For an old paint on a surface, it is a concentration greater than 0.5% by weight. Therefore, a paint containing small amounts of lead below the limit is not considered lead-based.

**Lead Poisoning.** Lead is an elemental metal found naturally throughout the environment. It is soluble in acidic solutions. Adverse effects have been noted in children at blood-lead concentrations as low as 10 mg/dL (22:252). Some of the symptoms of lead poisoning are weakness, hyperactivity, nausea, insomnia, reproductive difficulties, joint pain, and confusion (10:2).

**Micrograms/deciliter (mg/dL).** One millionth of a gram per tenth of a liter. Common units of measure for lead concentration in blood.

**Percent by weight (% w/w).** Unit weight of a component in a mixture per 100 unit weights of the mixture containing it.

**Pigment.** A compound added to a paint to give it opacity and/or color (25:347-389).

**Qualitative.** A qualitative test only indicates the presence or absence of a substance. It gives no indication of amounts or concentrations.

**Quantitative.** Quantitative tests provide data on total or relative amounts of substances.

**Reliability.** The ability of a test method to repeatedly give the same results regardless of the accuracy of the results. Encompasses both repeatability of results by a single tester and reproducibility of results by multiple testers.

**Sodium Rhodizonate.** A chemical compound used in some lead detection kits. Upon reaction with lead, it forms a pink to red complex.

**Sodium Sulfide.** A chemical compound used in some lead detection kits. Upon reaction with lead, it forms a grey to brown or black complex.

**Substrate.** Any base surface such as wood, metal, plaster, or brick that has been covered with a surface coating.

**X-Ray Fluorescence.** A method of analysis which irradiates the substance being tested with X-rays. Elements in the substance then emit various frequencies of radiation which are characteristic of the individual elements (9:25).

## Appendix B: Paint Manufacturer's Formulation

### **Hy Lux White**

<u>Approx. % wt.</u>	<u>Chemical Name</u>
25.	Titanium Dioxide
0.2	Cobalt
0.1	Zirconium
0.05	Manganese
44.65	Other Solids
30.	Volatiles

### **Hy Lux Yellow**

<u>Approx. % wt.</u>	<u>Chemical Name</u>
9.7	Lead Chromate as Lead
4.7	Non-hazard Yellow Pigment
5.5	Titanium Dioxide
0.2	Cobalt
0.2	Zirconium
0.07	Manganese
47.63	Other Solids
32.	Volatiles

Appendix C: Results of Laboratory Analysis

**CERTIFICATE OF ANALYSIS**

Sandra S. Henry  
645 ABW/EMX  
5490 Pearson Road  
Wright-Pat AFB, OH 45433-5332  
Contract # F3360-93-DW003

Date: June 16, 1993

Pg. 1

This is the Certificate of Analysis for the following samples:

Client Project ID: WPAFB  
Date Received: May 28, 1993  
Work Order: 953  
Number of Samples: 4  
Sample Type: Solid

**I. Introduction**

Four samples arrived at ITAS Cincinnati on May 28, 1993. The samples were collected on May 28, 1993 and were labeled as follows:

WPAFB Sample Identification	Sample Location
EM930789	Not specified on Chain of Custody
EM930790	Not specified on Chain of Custody
EM930791	Not specified on Chain of Custody
EM930792	Not specified on Chain of Custody

**II. Analytical Results/Methodology**

The analytical results for this report are presented by analytical test. The data will include sample identification information, the analytical results, and the appropriate detection limits.

The analyses requested and methods used are listed on the following page.

Reviewed and Approved by:

  
Tim Soward  
Project Manager

American Council of Independent Laboratories  
International Association of Environmental Testing Laboratories  
American Association for Laboratory Accreditation

Client: WPAFB  
Work Order: 953  
0595301

IT ANALYTICAL SERVICES  
CINCINNATI, OH

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II. Analytical Results/Methodology (cont.)

Pg. 2

- \* Total Arsenic by Graphite Furnace Atomic Absorption;  
EPA Method 7060
- \* Total Mercury by Cold Vapor Atomic Absorption;  
EPA Method 7471
- \* Total Barium, Cadmium, Chromium, Cobalt, Lead and Silver  
by Inductively Coupled Plasma Spectroscopy; EPA Method 6010

III. Quality Control

Immediately following the analytical data for the samples can be found the QA/QC information that pertains to these samples. The purpose of this information is to demonstrate that the data enclosed is scientifically valid and defensible. This QA/QC data is used to assess the laboratory's performance during the analysis of the samples it accompanies. All quantitations were performed within the calibrated range of the analytical instrument.



Client: WPAFB  
 Work Order: 953  
 0595302

IT ANALYTICAL SERVICES  
 CINCINNATI, OH

Analytical Results, ug/g

Pg. 3

Client Sample ID	EM930789	EM930790	EM930791	EM930792	Detection Limit
Analyte					
Arsenic	ND	ND	ND	ND	0.8
Barium	750	100	1700	1.1	0.2
Cadmium	0.92	0.96	2.4	ND	0.2
Chromium	660	87	1400	3.2	1.2
Cobalt	410	420	470	470	1.2
Lead	3200	410	6900	ND	8
Mercury	ND	ND	ND	ND	0.2
Silver	ND	ND	ND	11	2

ND = Not detected at or above the reported detection limit

Quality Control  
 Standard Reference Solution

Analyte	Theoretical Value	Percent Recovery
Arsenic	0.05	106, 104
Barium	97.4	94
Cadmium	70.3	103
Chromium	182	86
Cobalt	120	101
Lead	44.5	92
Mercury	0.003	101, 100
Silver	64.4	95

**CERTIFICATE OF ANALYSIS**

Sandra S. Henry  
645 ABW/EMX  
5490 Pearson Road  
Wright-Pat AFB, OH 45433-5332  
Contract # F3360-93-DW003

Date: July 7, 1993

Pg. 1

This is the Certificate of Analysis for the following samples:

Client Project ID: WPAFB  
Date Received: June 25, 1993  
Work Order: 1238  
Number of Samples: 4  
Sample Type: Paint Chips

**I. Introduction**

Four samples arrived at ITAS Cincinnati on June 25, 1993. The samples were collected on June 23, 1993 and were labeled as follows:

WPAFB Sample  
Identification

Sample Location

EM930927  
EM930928  
EM930929  
EM930930

**II. Analytical Results/Methodology**

The analytical results for this report are presented by analytical test. The data will include sample identification information, the analytical results, and the appropriate detection limits.

The analyses requested and methods used are listed on the following page.

Reviewed and Approved by:

  
Tim Soward  
Project Manager

Client: WPAFB  
Work Order: 1238  
06123801

IT ANALYTICAL SERVICES  
CINCINNATI, OH

Pg. 2

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## II. Analytical Results/Methodology (cont.)

- \* Lead by Inductively Coupled Plasma Spectroscopy;  
EPA Method 6010

## III. Quality Control

Immediately following the analytical data for the samples can be found the QA/QC information that pertains to these samples. The purpose of this information is to demonstrate that the data enclosed is scientifically valid and defensible. This QA/QC data is used to assess the laboratory's performance during the analysis of the samples it accompanies. All quantitations were performed within the calibrated range of the analytical instrument.

Client: WPAFB  
Work Order: 1238  
06123802

IT ANALYTICAL SERVICES  
CINCINNATI, OH

Pg. 3

Analytical Results, ug/g

Client Sample ID	Sample Location	Lead
EM930927		4700
EM930928		13000
EM930929		710
EM930930		2000
Method Blank - PBS 1		ND *
Method Blank - PBS 2		1.3 *
Detection Limit		6.7
* Detection Limit = 1		

Quality Assurance Data

Quality Control  
Standard Reference Solutions

Analyte	Theoretical Value	Percent Recovery
Lead	1.25	94, 97

## Appendix D: Instructions for Use of Test Kits

### Modified Instructions

#### **General Instructions for All Test Kits:**

1. The test sheets consist of 14 - 12 x 12 inch pieces of plywood. The sheets are labeled on the back with letters A through G, two of each letter. The sheets are each divided into a 10 x 10 grid of squares.
2. With fine sand paper and using a twisting motion under thumb or finger pressure, scuff a patch of the paint surface in the number of squares needed as indicated by Step 3. Do not do more than what is immediately needed (ten, then five more, then five more, etc.). **Be sure to use a different piece of sand paper for each test sheet!**
3. Start by doing ten tests with one kit on one sheet.
  - If one or more results are different from the others do five more.

**Then**

  - If a total of three or more results (of the 15 now completed) are different from the others do five more.

**Then**

  - If a total of five or more results (of the 20 now completed) are different from the others do five more.

**Then**

  - If a total of nine or more results (of the 25 now completed) are different from the others do five more.

#### **Kit Specific Instructions**

**Acc-U-Test and Lead Detective** - Plastic dropper bottles.

1. At the beginning of each day of testing, check the solution by placing one drop of solution on the lead-acetate paper. If the solution turns the paper brown or black, the solution is still active.
2. Place one drop of solution on each scuffed patch of the sheet currently being tested. Be careful not to touch the dropper tip to the paint.
3. A positive result is indicated by a change in color ranging from gray to black. For each square showing a positive result, indicate on the data sheet a "+" for gray/barely discernible, a "++" for dark gray/easily

discernible, or a "+++" for black/obvious. Also, indicate the approximate time required for the color change to occur.

4. If no color change occurs the result is negative. Allow a maximum of 30 minutes for the color change to occur. For each square on which there is no change, record a "-" on the data sheet. Other colors such as red, blue, or green are also negative results for lead.

5. Repeat Steps 3 - 4 as required to meet the requirements of Step 3 in the General Instructions.

**LeadCheck** - Individual cardboard-lined swabs.

1. With the swab tip pointing up, crush the swab tube with your fingers at the points marked "A" and "B". Crush Point A first and then Point B.

2. With the swab tip pointing down, shake the swab two or three times.

3. Hold the swab tip over the scuffed patch to be tested and gently squeeze the tube until two or three drops fall onto the scuffed patch. Now, while continuing to squeeze the tube, gently rub the swab tip on the patch for 30 seconds. **Use one swab for each scuffed patch!**

4. A positive result is indicated by a change in color on the paint ranging from pink to red. For each square showing a positive result, indicate on the data sheet a "+" for pink/barely discernible, a "++" for dark pink/easily discernible, or a "+++" for red/obvious. Also, indicate the approximate time required for the color change to occur.

5. If no color change occurs the result is negative. Allow a maximum of 30 minutes for the color change to occur. For each square on which there is no change, record a "-" on the data sheet. Other colors such as yellow or orange are also negative results for lead.

6. Repeat Steps 1 - 5 as required to meet the requirements of Step 3 in the General Instructions.

**Lead Alert** - White dropper bottle with leaching solution and clear dropper bottle with yellow indicating solution.

1. Place a piece of filter paper on each scuffed patch to be tested.

2. Put two drops of leaching solution on each piece of filter paper.
3. Allow to stand for 30 minutes then place two drops of indicating solution on the filter paper.
4. A positive result is indicated by a change in color ranging from pink to red. For each square showing a positive result, indicate on the data sheet a "+" for pink/barely discernible, a "++" for dark pink/easily discernible, or a "+++" for red/obvious. Also, indicate the approximate time required for the color change to occur.
5. If no color change occurs the result is negative. For each square on which there is no change, record a "--" on the data sheet. Other colors such as yellow or orange are also negative results for lead.
6. Repeat Steps 1 - 5 as required to meet the requirements of Step 3 in the General Instructions.

**EM Lead Test** - Black dropper bottle of reagent and white test strips.

1. Put two to three drops of reagent on each scuffed patch to be tested.
2. Stir the reagent around several times with the upper end of a test strip and allow to stand for 30 minutes.
3. Gently press the reaction zone of the test strip onto the surface to allow the reagent to soak into the reaction zone. **Use one test strip for each scuffed patch!**
4. After one minute, compare the reaction zone with the color scale on the test strip canister. A positive result is indicated by a change in color ranging from pink to red. For each square showing a positive result, indicate on the data sheet a "+" for pink/barely discernible, a "++" for dark pink/easily discernible, or a "+++" for red/obvious. Also, indicate the approximate time required for the color change to occur.
5. If no color change occurs the result is negative. For each square on which there is no change, record a "--" on the data sheet. Other colors such as yellow or orange are also negative results for lead.
6. Repeat Steps 1 - 5 as required to meet the requirements of Step 3 in the General Instructions.

# LeadCheck

S W A B S

## LEAD TEST KIT

### Instruction Manual

#### PLEASE READ CAREFULLY

**LeadCheck Swabs** provide a convenient method for the detection of lead on painted wood or metal surfaces, toys, ceramics, glassware, furniture and other items. This innovative and patented test can alert the user to the presence of lead so that proper action can be taken to avoid the harmful effects which lead can produce. This test is not intended to be quantitative – please consult a lead inspector, a testing laboratory or your Department of Health when items or areas test positive for lead.

#### Health Hazards of Lead

Lead poisoning can cause severe health effects including damage to the liver, kidneys, brain, nerves, bones and blood. Children are especially at high-risk because they routinely ingest non-food items contaminated with lead. Toxic levels of lead can cause permanent learning disabilities, retardation and even brain damage in young children. Documentation reveals that serious behavioral problems and learning disabilities are seven times more likely to occur in children exposed to low-levels of lead over an extended period of time (*The New England Journal of Medicine* – January 11, 1990). In adults, lead poisoning can cause high blood pressure and reproductive problems. In pregnant women, the fetus is particularly vulnerable to lead's toxic effects.

#### Symptoms of Lead Poisoning

Symptoms include: fatigue, pallor, loss of appetite, irritability, sleep disturbance, sudden behavioral change and developmental regression. More serious symptoms include clumsiness, muscular irregularity, abdominal pain, persistent vomiting, constipation and changes in consciousness. Anyone who displays these symptoms should receive a thorough medical examination.

#### GENERAL INSTRUCTIONS

**LeadCheck Swabs** contain two glass ampoules of non-hazardous testing chemicals. For ALL TESTING APPLICATIONS, use the following steps to activate the Swab (see Diagram on back of package):

1. **CRUSH** – With the Swab tip pointing up, squeeze and crush points marked "A" and "B" located on the barrel of the Swab.
2. **SHAKE AND SQUEEZE** – With the Swab tip pointing down, shake twice and squeeze gently until the yellow liquid appears on the Swab tip – *the Swab is now activated for testing.*
3. **RUB** – While squeezing gently, rub the Swab tip on the test area for 30 seconds. (NOTE: See **SPECIAL INSTRUCTIONS** for testing specific items/areas.)

#### TEST RESULTS

If the Swab tip turns pink, the test is positive – **LEAD IS PRESENT**. If the Swab indicates no color change, the test is negative and no leachable lead has been detected. Proceed to the Test Confirmation Card to verify ALL NEGATIVE results. All testing must be completed within two (2) minutes.

(NOTE: When a Swab tip turns pink, indicating a positive result (lead is present), the Swab may no longer be used. Swabs must be used immediately after being activated. Swabs are not reusable.)

#### TEST CONFIRMATION CARD

Included with your **LeadCheck** Test Kit is a Test Confirmation Card. On each card are test dots, each containing a small amount of lead. The Test Confirmation Card is used to confirm a NEGATIVE RESULT. If the Swab tip does NOT turn pink after testing the item or area, rub the tip of the Swab on one of the unused test dots. If a pink or red color appears on either the dot or the Swab, the test was performed properly and you did obtain a TRUE NEGATIVE RESULT. Be sure to use the Test Confirmation Card at the end of 2 minutes of testing, if the Swab did not turn pink on any of the items tested. If the test dot and/or Swab tip does not turn pink or red, the test was invalid and must be repeated with a new **LeadCheck Swab**. ALL NEGATIVE RESULTS MUST BE CONFIRMED WITH THE TEST CONFIRMATION CARD.

#### TESTING PRECAUTIONS

1. Test Confirmation Cards contain small amounts of lead. Keep all lead-containing items and **LeadCheck** Test Kits secure – **KEEP OUT OF THE REACH OF CHILDREN.**
2. Do not touch the Swab tip – wash hands after use.
3. If the test is positive, exercise caution in handling the item or material. Consult with a lead inspector, testing laboratory or your Department of Health.
4. Surfaces which become pink during testing may be washed with an all-purpose household cleaner.
5. **LeadCheck Swabs** CANNOT be used to detect lead in water.

#### SPECIAL INSTRUCTIONS

The following instructions are provided for specific items and areas to be tested with **LeadCheck Swabs**. PLEASE READ THOROUGHLY.

##### Painted Wood or Metal Surfaces

House paint contained lead until 1978. Old varnishes and lacquers may also be lead-containing. To test any painted, varnished or lacquered surface:

1. Clean and remove all dust and dirt from the area to be tested.
2. With a clean knife or scraper, cut a small 1/4" notch at a diagonal to expose all painted layers down to the bare surface – lead may be present in any layer of paint.
3. Rub the activated Swab in the exposed cross-section for 30 seconds. If any of the layers contain lead, a positive result will occur – the Swab or surface will turn pink. (NOTE: See steps 1 through 3 in **GENERAL INSTRUCTIONS**.)

#### PAINT TESTING PRECAUTIONS

1. Red Painted Surfaces – "Bleeding" may occur when testing surfaces that are painted red. Moisten cotton-tipped applicators with a few drops of distilled white vinegar. Rub the moistened cotton on red surface. If red appears on the cotton, **LeadCheck Swabs** cannot be used. Call **LeadCheck** (1-800-262-LEAD) for additional information.
2. Gypsum, Plaster Dust and Stucco – Sulfates present in gypsum, plaster dust and stucco can interfere with the color development on the Swab



Tests performed on painted walls free of gypsum or plaster dust are valid. **BE SURE TO USE THE TEST CONFIRMATION CARD TO VERIFY PROPER TESTING.** If pink is not seen on either the test dot or the Swab, it is likely that plaster dust has interfered with the color development and the test is not valid. Call **LeadCheck (1-800-262-LEAD)** for additional information.

3. **Color Development Time** – With certain paints, lead is difficult to extract and it may take longer for positive test results to develop. Examine the test surface 30 to 60 minutes after the test has been performed before assuming a test result. Further quantitative measurements are needed to determine the level of lead in such paints. Consult with a lead inspector, testing laboratory or your Department of Health.
4. **Other Colors** – Some paints contain barium sulfate (an extender) which will produce an "orange" color on the Swab tip. Barium is less toxic than lead and no special precautions need to be taken. If the Swab turns pink over the orange color, a positive result is indicated and lead is present.

*(NOTE: If test results prove negative on a house painted prior to 1978, and you are concerned that lead is present, call a lead-paint inspector or send a paint chip to a testing laboratory for analysis.)*

### Dust

Lead-containing dust is the main route for lead poisoning in children. Renovations involving lead-based paint can create dangerous levels of lead-paint dust. The following procedures are used to test for lead in dust.

For non-leaded surfaces (e.g. wood, linoleum or carpet):

1. Activate the **LeadCheck Swab** (see GENERAL INSTRUCTIONS).
2. Rub the activated Swab in the dust for 30 seconds. If the dust contains lead, the Swab tip will turn pink. *(NOTE: Avoid rubbing the Swab into large amounts of "dirt dust" as this will obscure the color test results on the Swab.)*

For leaded surfaces (e.g. windowsill painted with lead paint):

1. Collect a small sample of paint onto a non-leaded surface such as a plastic dish or piece of wax paper.
2. Activate the **LeadCheck Swab** (see GENERAL INSTRUCTIONS).
3. Rub the activated Swab in the dust for 30 seconds. If the dust contains lead, a positive result will occur.

### Ceramics and Lead Crystal

Improper manufacture of glazed ceramicware or lead crystal can allow lead to leach from the item's surface into food. Use the following procedure to test ceramicware and lead crystal for leachable lead:

1. Activate the **LeadCheck Swab** (see GENERAL INSTRUCTIONS).
2. Rub the Swab over all patterns containing different colored glazes and any cracks or chipped areas. If lead is leaching from the surface, the Swab will turn pink. You should test at least 10% of any set of ceramicware.
3. When testing lead crystal, rub the Swab on the inside surface of the wine glass, decanter or other vessel.

### Solder (Plumbing and Food Cans)

The following procedure will test for lead in solder used to join copper piping and seams of cans:

1. Wipe off the solder joint with a paper towel or cloth.
2. Using an emery board or sandpaper, lightly score the surface to be tested.
3. Activate the **LeadCheck Swab** (see GENERAL INSTRUCTIONS).
4. Squeeze one drop of yellow liquid from the Swab onto the solder surface.
5. Touch the Swab tip to the wet solder surface and rub gently for **ONLY 10 SECONDS OR LESS**.
6. The Swab will turn pink if the solder contains greater than 2% lead. *(NOTE: Rubbing the Swab too long or too hard may cause a metallic film to be deposited on the Swab tip and a purple color will result. If the color purple is obtained, the test must be repeated with a new LeadCheck Swab.)*

### Lead Foils (Wine/Champagne Bottles)

To test for lead in foil used to wrap bottles, follow steps 1 - 6 under **SOLDER** testing. *(NOTE: If a bottle is sealed with lead foil, before uncorking, thoroughly wipe the bottle top with a rag or sponge moistened with vinegar or lemon juice.)*

### Soil

Using **LeadCheck Swabs**, the following procedure will test soil for high lead content:

1. Place approximately equal amounts of soil from various areas in a flexible plastic bag. Mix dirt thoroughly, breaking up any large clumps.
2. Place one teaspoon of the mixed soil, along with two teaspoons of reconstituted lemon juice into a non-leaded glass (or plastic) container.

3. Thoroughly mix the dirt and lemon juice together.
4. Allow the dirt to settle overnight at room temperature.
5. The following morning, remove one small drop of liquid above the dirt and place it on a piece of plastic wrap or waxed paper. *(NOTE: Too large of a drop of liquid dilutes the lead reactive material on the Swab, causing an inaccurate test result.)*
6. Activate the **LeadCheck Swab** (see GENERAL INSTRUCTIONS).
7. Rub the Swab tip in the drop of liquid for **ABOUT 15 SECONDS**.
8. The Swab, paper, or both will show a positive result if **HIGH LEVELS** of extractable lead are present in the soil tested. *(NOTE: Some soils may completely absorb the two teaspoons of lemon juice. If your soil sample does not leave a layer of liquid above it, repeat the test with more lemon juice.)*

If you still suspect lead contamination after obtaining a negative result, you can send a soil sample to a state or commercial laboratory to obtain a quantitative result.

### WARRANTIES

**LeadCheck Swabs** provide a convenient method for the detection of leachable lead in glazed ceramics, pottery, decorated glassware, dust, soldered plumbing and food cans, paint chips, and any painted surface. This test is a presumptive test for lead and should not be considered quantitative. Under controlled laboratory conditions, **LeadCheck Swabs** will reproducibly detect 1 - 2 micrograms of lead leaching out of dishes. Under the conditions described in the instructions, **LeadCheck Swabs** will detect (high) levels of leachable lead that exceed government regulations. Use of this test is not intended to replace a professional inspection. No guarantees are intended or implied.

### LIABILITY

The manufacturer assumes no liability for the misuse of **LeadCheck Swabs** or for the interpretation of the results by the user. If lead contamination is suspected based upon this test, consult a lead-testing specialist, a professional testing laboratory or your local Department of Public Health.

**HybriVet Systems, Inc.**  
P.O. BOX 1210  
Framingham, MA 01701  
1-800-262-LEAD

\* This product is protected under U.S. Patent No. 5,039,618

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Merckoquant® 10 077

## Lead Test

Test strips and reagent for the detection and semiquantitative determination of lead ions

### General

The Merckoquant® Lead test strip is suitable for the semiquantitative determination of lead ions in solutions and for the detection of metallic lead and lead compounds on surfaces.

In spite of its toxicity (accumulation of lead in the body [saturnism] through inhalation and absorption of lead vapours and dust) lead is used for many purposes such as cable sheathing, radiation protection against X-ray and gamma radiation, accumulators, manufacture of containers and tubes, in paints (red lead) as well as in tetraethyllead (antiknock compound in petrol), because of its versatility and ease of processing (soft and malleable) as well as its resistance to corrosive liquids.

The lead detectable in the environment (waters, soils, foods) mainly originates from automotive exhaust gases from the combustion of leaded petrol. Lead and lead oxide are formed which enter the atmosphere and can also be detected in the exhaust pipe so that it can be ascertained whether a vehicle has been run on leaded petrol or not.

Poisoning of a catalytic converter can also be detected. The catalytic converter is rendered useless by malicious or accidental use of leaded petrol so that high concentrations of NO<sub>x</sub> compounds enter the atmosphere with the exhaust gases.

The Merckoquant® Lead Test only detects ionic lead and not organic compounds of lead such as tetraethyllead in petrol.

### Method of determination

In acidic solution lead reacts with rodizonic acid to form a red coloured complex.

### Directions for use

In aqueous solutions:

1. Rinse the measuring vessel with the solution to be tested and fill to the 5-ml mark.
2. Add 2 drops of reagent (acetic acid) and mix carefully.
3. Dip the reaction zone of the test strip in the solution to be tested for 1 second such that the reaction zone is properly wetted. Wipe the edge of the test strip against the edge of the vessel to remove excess liquid.
4. Compare the reaction zone with the colour scale after 2 minutes.

### Remarks

The pH of the solution to be tested should lie between 2 and 5. This is normally achieved with the reagent. If the pH value is not obtained with the amount of reagent given in the Directions for use (check with a pH indicator strip), strongly acidic solutions must be buffered with 1 mol/l sodium hydroxide solution and alkaline solutions with 1 mol/l nitric acid.

No further reagent is required and solutions which already lie within the correct pH range do not require any reagent either.

On surfaces:

- A) 1. Drop 1—3 drops of reagent onto the surface to be tested.
2. Stir the reagent around several times with the upper end of the test strip and leave to react for 1 minute.
  3. Briefly gently press the reaction zone of the test strip onto the surface to allow the solution to soak into the reaction zone.
  4. After 1 minute, compare the reaction zone with the colour scale.
- B) 1. Moisten the reaction zone of the test strip with 1 drop of reagent and immediately gently press against the surface to be tested for 2 minutes.
2. Compare the reaction zone with the colour scale.

Evaluation: any red coloration indicates the presence of lead. If the reaction zone is colorless to yellow, no lead is present.

If it is not possible to conduct a direct determination on a surface, for instance if it is inaccessible as with an exhaust pipe which is turned down at an angle, a sample from the surface to be tested must be transferred to the measuring vessel to be able to conduct a determination.

1. Scrape a little of the exhaust residue into the measuring vessel using for instance a screwdriver.
2. Add 5 drops of reagent, mix and leave to react for 1 minute.
3. Dip the reaction zone of the test strip into the solution to be tested for 1 second such that the reaction zone is fully wetted. Wipe the edge of the test strip against the edge of the vessel to remove excess liquid.
4. After 1 minute, compare the reaction zone with the colour scale.

Evaluation: Any red coloration indicates the presence of lead. If the reaction zone is colorless to yellow, no lead is present.

For further information (e.g. on interference by anions and cations) please send for our Merckoquant® Tests leaflet.

### **Storage**

The package should be stored cool (5—20 °C) and dry. Immediately reclose the tube after removing the necessary test strips and replace the screw cap on the reagent bottle.

### **Safety precautions**

Store test kits such that they cannot fall into the hands of children, instruct young persons as to the safety precautions. Avoid contact with skin and eyes (the reagent contains dilute acetic acid), also do not touch the reaction zone. After completion of the determination, wash away the sample in a place where no contact with food or eating utensils is possible. Thoroughly wash away with water and immediately wash the hands.

### **Further rapid tests**

Numerous colorimetric and titrimetric rapid tests as well as ion-specific Merckoquant® test strips are available for the determination of further ions and compounds.

Our brochure "Rapid test kits for analyzing water, soil samples, solids, foodstuffs" provides further information on the overall range.

E. Merck, Postfach 41 19, D-6100 Darmstadt 1,  
Tel. (0 61 51) 7 20, Telex 4 19 328-0 em d

### LIMITED WARRANTY

Pace Environs, Inc. (Pace) warrants to the original retail purchaser (you) that this Lead Alert Kit is free from defects in materials at the time of your original retail purchase. Pace will, without charge, replace defective items or (at Pace's option) refund the purchase price you paid, provided you return the Lead Alert Kit and a copy of your dated proof of purchase to Pace within 60 days from the date of original retail purchase. This warranty does not cover damage resulting from accident, abuse or misuse.

Pace makes no representation or warranty concerning, and assumes no responsibility for, the results obtained from this product or the interpretation of such results.

All implied warranties, including implied warranties of merchantability and fitness for a particular purpose, are limited in duration to 60 days from the date of your original retail purchase.

The foregoing states Pace's entire obligation and your sole remedies for breach of warranty, whether express or implied, and the above warranty is in lieu of all other express warranties, whether oral or written. In no event will Pace or anyone involved in the manufacture or distribution of this product be liable for consequential, incidental or other damages in connection with this product, or for any amount in excess of the purchase price you paid. No one is authorized to modify this warranty or to assume any other liability on behalf of Pace in connection with this product.

Some states do not allow limitations on how long an implied warranty lasts or the exclusion or limitation of incidental or consequential damages, so the above limitations or exclusions may not apply to you. This warranty gives you specific legal rights, and you may also have other rights which vary from state to state.

For warranty claims, contact Pace at 81 Finchdene Square, Scarborough, Ontario, M1X1B4, Canada.

For warranty or technical information call (416) 293-5008

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CARY, N.C. - SCARBOROUGH, ONT.

0292PC-1

### EASY INSTRUCTIONS FOR FRANDON™

# LEAD ALERT KIT

Protected Under U.S. Patent Nos. 4,873,197; 5,010,020

### Detects Lead in the Home Environment

#### GOAL OF THIS KIT

The goal of this test kit is to provide a simple method to alert users to the presence of dangerous levels of lead in a variety of materials often found in the home.

#### CONTENTS OF THIS KIT

Dark brown-red tablets	One each (two if 100 test kit)
Indicating Solution	One each (two if 100 test kit), red top bottles
Leaching Solution	One each, white bottle
Test papers	(100 test kit)
Abrasive strips	In recloseable pouch; use each strip only once
Applicators	Lead-free cotton-tipped swabs in recloseable protective pouch; use each applicator tip only once
Positive Control	A strip with six circles. Use to confirm effectiveness of testing system.
Plastic box	Can be used as a viewing surface
Instructions	

## HOW TO PREPARE INDICATING SOLUTION

1. Remove red cap from plastic bottle labelled "Indicating Solution."
2. Carefully remove the dropper insert by rolling/twisting it to the side.
3. Open the tablet container and place only one tablet into the solution.
4. Replace the dropper insert and the red cap and shake the bottle for one minute. Allow the bottle to stand for five minutes and then shake it again until the solution turns yellow. The tablet will not be completely dissolved. This is normal.

The Indicating Solution, once prepared, is designed to be effective for at least three days at room temperature, provided the solution is stored in a dark, cool place. Most testing will normally be completed in a matter of minutes or hours. If your testing is interrupted for any reason, we suggest putting all contents of the kit back in the box, securing the lid and storing in a closed drawer. If testing has been interrupted for more than 24 hours, prior to commencing further testing we recommend you perform a Positive Control Test included with this kit.

### How to perform the Positive Control Test

Use this test to verify that the testing system is working properly, to give visual indication of the rose color and to give you confidence in your results. The test may be performed up to six times.

1. Place two drops of Leaching Solution and two drops of Indicating Solution on one tip of applicator.
2. Press the applicator tip against the center of one of the numbered circles that has not previously been used on the Solution Test Strip.
3. A pinkish stain will appear on the applicator tip and/or on the circle. This indicates that the FRANDON™ LEAD ALERT test system is working correctly. If a pinkish stain does not appear, the Indicating Solution has expired.

**Caution:** For testing purposes, the areas inside the circles of the Solution Test Strip contain minute amounts of lead. Do not touch these areas. Wash hands after use. Keep away from children.

## SPECIFIC TEST INSTRUCTIONS

### Painted surfaces, paint chips

Lead-contaminated peeling paint and paint dust are the leading causes of childhood lead poisoning, according to the government. Lead paint can also cause fetal and adult lead poisoning. Lead paint used in homes was not outlawed in the U.S. until 1978. Therefore, renovations, remodeling or painting/decorating projects should never be undertaken in homes built before 1978 without first testing all layers of paint. Even if the top layer of paint tests lead free, underlying coats of paint may contain lead, which, when sanded, scraped or heated will enter the air in the form of dust. From there it can be inhaled, or it can settle on the floor and furniture where children can ingest it by putting their hands into their mouths. If a child eats only three particles of lead the size of sugar crystals every day, over time that child will most certainly suffer the effects of lead poisoning.

Before testing red paint, check for "bleeding" by rubbing area with a cotton ball or fresh applicator tip soaked in distilled white vinegar. If red pigment "bleeds" onto the cotton, this kit and others like it cannot be used to test that area.

When testing painted surfaces, start with the top layer and work through all other layers. Use the General Instructions to test the top layer; follow instructions below for underlying layers.

### Underlying layers of paint

*Always test every layer of paint, from top layer down.*

1. Sand a small area (approximately one-half square inch) with an abrasive strip to expose the underlying surface layer.
2. Test the exposed layer using the General Instructions. Use a new abrasive strip for each test.

### Particles of paint, metal, dust, etc.

1. Apply two drops of Leaching Solution to applicator tip.
2. Apply a very small amount of fine particles of the material to be tested (such as ground paint chips or paint dust, house dust, or dust from vacuum cleaner bag) to the moistened applicator tip.

3. Apply one or two more drops of Leaching Solution over the particles on applicator tip. Wait 30 seconds.
4. Apply 5 drops of Indicating solution to applicator tip and watch for color change.

#### Ceramic & enameled dishes, mugs, tea cups

*Use the General Instructions or the following method (100 test kits) as described by the U.S. Food & Drug Administration, which has used our kits for testing ceramics.\**

1. Place one test paper on a clean dry smooth horizontal surface of the item to be tested. If the item is patterned with painted decorations or decals, a portion of the pattern is an ideal test spot.
2. Apply two drops of Leaching Solution to different areas of the test paper. The paper must be saturated, not just moist, but there should be no excess solution present. The paper must be in complete contact with the surface with no ridges or bubbles present. The moist paper will be almost transparent and the pattern of the item will be visible.
3. Allow the test paper to remain on the item until dry (normally 5 to 10 minutes). Then remove it from the item and place it on a clean white surface for viewing.
4. Apply two drops of Indicating Solution to different areas of the test paper. A rose to rose/red colored stain will appear on the test paper if lead has been released. The pattern of the stain corresponds exactly to the location on the surface that released lead. In many cases, the design of the pattern (or decal) that released lead will be clearly visible on the test paper.

#### Household plumbing – pipes, joints and fixtures

The widespread use of lead, in the form of leaded pipe and lead-containing soldered joints in copper pipe, poses a serious health hazard. In some cases, particularly in areas having corrosive water, significant lead contamination can occur in a building's own water piping. If your pipes or soldered joints test positive for lead, as a precaution run the water for at least two minutes from any tap that has not been used in several hours. Be sure to check the water line to your refrigerator if it has an automatic ice maker or a water tap. There are documented cases of serious lead poisoning, particularly to infants, from this source. Local authorities should

know if leaded piping exists in the main water supply system. If the water comes in contact with lead anywhere along the way to your faucet, it is advisable to have the water itself tested for lead contamination.

1. Locate an area where water pipes are exposed and determine if soldered joints are present – these are the areas with silver-colored metallic surfaces. A greenish-colored corrosion may also be evident.
2. Sand the pipe and/or the soldered joint lightly with an abrasive strip to remove corrosion and expose a portion of the bare metal surface. Use a new abrasive strip for each test.
3. Test for lead using the General Instructions.

#### Soldered seams on food cans

It has been known for decades that lead migrates into food from lead-soldered seams on metal food containers ("tin cans"). Although newer and safer methods for sealing food cans are available today, about 4% of food cans produced in the U.S. and a much higher percentage of imported cans are sealed with lead solder. The combined total, domestic and imported, indicates that hundreds of millions of lead soldered cans are placed on market shelves in the U.S. each year.

1. Peel back label to expose vertical side seam.
2. If the seam appears as a clean black line, the can was welded without lead.
3. If the seam has a coating of silver-colored metal, it has been soldered. Test for lead using the General Instructions.
4. If the outside of the seam tests positive, carefully examine the inside of the can. If the protective coating on the inside of the can is degraded, test the inside seam for lead release. Wash and rinse the inside of the can, and dry it well with a paper towel before testing. If the inside seam tests positive for lead, the contents are probably tainted with lead.

#### Printed food storage bags

Printing on bread bags and other plastic covering is often loaded with lead. Scientific studies indicate that these bags will release hazardous amounts of lead into food if the food comes in contact with the printing. To test for lead, follow the General Instructions.



## HOW TO TEST FOR LEAD - GENERAL INSTRUCTIONS

- Important:**
- Read and understand all of the instructions in this booklet before testing.
  - Frandon™ Lead Alert Kits contain non-toxic reagents. Even so, we suggest you keep all contents away from children, wash hands after use and avoid contacting eyes with solutions. If contact occurs, flush eyes thoroughly with water.
  - Use care when handling Positive Control Strip.

*Follow these instructions in their exact order.*

1. Prepare Indicating Solution (see inside).
2. Apply two drops of Leaching Solution to tip of applicator (or test paper placed on surface to be tested) – FIG. 1.
3. Rub the cotton tip on the surface to be tested for 10-15 seconds (or allow the filter paper to dry on the surface) – FIG. 2.
4. Add two drops of Indicating Solution to the applicator (or test paper).
5. Interpret the results as follows:

**Positive Result** – The appearance of a pinkish to rose/red color. This indicates that lead is being released – FIG. 3.

**Negative Result** – The appearance of a yellow stain that fades away within a few minutes. This means that lead is not being released or is not being released in significant amounts.

FIG. 1



FIG. 2



FIG. 3



### **IF YOU GET A POSITIVE RESULT**

A positive result occurs when the applicator tip or filter paper turns pinkish to rose/red. Paint that tests positive should not be sanded or scraped. Lead poisoning could result from inhalation or ingestion (eating) of paint chips or particles that spread throughout your home as a result of sanding or scraping.

Based on published data from EPA studies conducted during 1991 the Frandon™ Lead Alert Kit has greater sensitivity in detecting lead in paint than does major competition. Additionally, in this study the Frandon™ Lead Alert Kit consistently picks up lead at 0.6 micrograms, and is shown to be considerably more sensitive than major competitive products.\*

If the liquid or food contact surface of a ceramic cup, mug, pitcher or plate shows a strong positive result, lead could migrate into food or drink that is prepared, served or stored in the item.

If you wish to determine the exact amount of lead being released, contact a qualified laboratory. A qualified laboratory will also be able to confirm lead release that may occur at levels below the detection limits of this test kit. Your local public health department should be able to assist you.

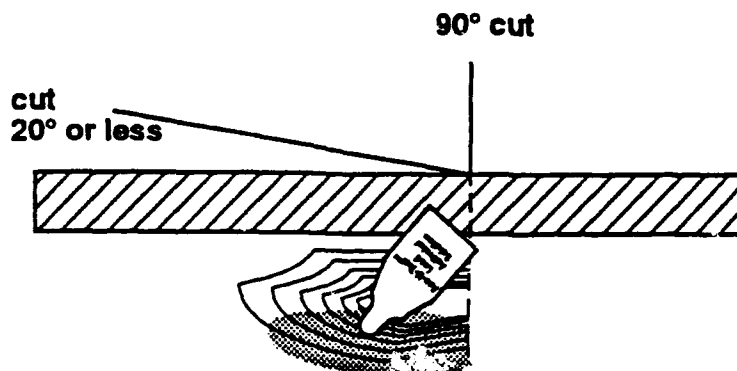
\* Note: Neither the Environmental Protection Agency nor the Food & Drug Administration endorses or recommends any commercial products.

# Testing with Acc-U-Test™ Lead Activator Solution

*Properly following directions is the key—  
safe and accurate testing is the result.*

## How to Use the Acc-U-Test™ Lead Activator Solution to Perform an Inspection

1. Using a razor knife or similar tool, carefully slice into the painted surface so as to expose all layers of paint much like a slice of onion or fingerprint (do this in a spot not easily noticed).
2. Illuminate the area where necessary and examine the cut with your magnifying glasses to insure all layers of paint are exposed down to the base material.
3. Place a small quantity of Acc-U-Test™ Lead Activator Solution on one half of the cut, this will allow you to compare your results.
4. A positive result is indicated by a change in color from gray to black depending on the amount of lead in the paint.
5. If no color change occurs the result is negative. A darkening of the paint i.e. bright red to a darker shade of red is a negative for lead.
6. Should other color change occur, i.e. red, blue, green, etc., these are also negative for lead content.
7. Test all surfaces even if they appear to be unpainted, Antiquing and feather painting can hide several layers of paint.
8. Dark or black paints can be tested using the method for dust or pottery.
9. Be alert for single layers of lead paint sandwiched between multiple layers of non-lead paint.
10. Testing should be performed on suggested areas both inside and outside the dwelling.



**Cutting a paint chip sample from a window sill.  
Apply solution to lower half of chip.**

# Testing for Sources of Lead

## Other than Paint

Although paint is by far the most likely source of lead poisoning, you should be alert to the possibility of other sources of lead in the environment which may contribute to the body's overall lead burden (dust, toys, pottery, water etc.).

### Testing a Dust Sample

1. Take an alcohol-based towelette and using a thorough wiping motion, wipe the area to be tested.
2. Fold the towelette back into itself in order to hold the dust.
3. Place your sample in a small plastic, glass, or similar lead-free container.
4. Add enough 4-5% white distilled vinegar to cover the towelette.
5. Cover and let stand 8 hours or overnight.
6. After allowing the sample to set, place a small amount of the vinegar into a small lead-free cup (white paper, clear plastic or styrofoam will do).
7. Take the liquid outside of the building. *The harmless odor created by adding the Acc-U-Test™ Lead Activator Solution will be unpleasant, so it is advisable not to perform this part of the test indoors.*
8. Add one or two drops of Acc-U-Test™ Lead Activator Solution to the vinegar.
9. A reaction in color from milky gray to brown/black indicates lead in the dust.

### Testing Pottery

1. Fill the cup, dish, plate, bowl, etc., with 4-5% white distilled vinegar. Or, or place the item in a lead-free container and add 4-5% white distilled vinegar.
2. After letting the vinegar set for 24 hours, pour a small amount (an ounce or so) into a clear plastic or white paper or styrofoam cup.
3. Take this outside of the building. *The harmless odor created by adding the Acc-U-Test™ Lead Activator Solution will be unpleasant, so it is advisable not to perform this part of the test indoors.*
4. Then add a few drops of the Acc-U-Test™ Lead Activator Solution. If the vinegar turns milky gray to brown/black, the item tested contains lead and should not be used for food or drink.

This kit was developed by professionals with more than 20 years experience in testing for lead hazards in the home. The kit was developed for the convenience of the home owner. It should not, however, be used as or considered a regulatory tool.

If interpretation of the test results is difficult, or if a complete lead inspection is desired, you should contact Acc-U-Test™, your local laboratory or a professional lead inspector for a full analysis.

## **Precautions**

Our Acc-U-Test™ Lead Activator Solution is no more hazardous than ordinary household bleach, however, common sense precautions should be followed as you would with any chemical.

- **Avoid Contact With Eyes.** Should eye contact be made, flush with clear water for fifteen minutes and call a physician immediately.
- **Skin Contact.** Should skin contact be made, wash with soap and water when possible.
- **Do Not Leave Unattended.**
- **Allergic Reaction.** In the unlikely event of allergic reaction to the chemical (it smells a bit like egg salad), discontinue use and provide fresh air. Wear disposable plastic gloves if allergic to the solution.
- **Wear Safety Glasses.** Use glasses that double as magnifying glasses.

## **Care of Acc-U-Test™ Lead Activator Solution**

1. Store tightly capped
2. Keep away from children
3. The shelf life of the solution is more than 1 year.

## **Some Recommended Areas to Test**

Suggested areas to test for lead are indicated with arrows on the drawings on the reverse side of this flyer.

### **Other Products and Services Available**

**Acc-U-Test™ Lead Hazard Franchises Available**

**Inspector Training Programs**

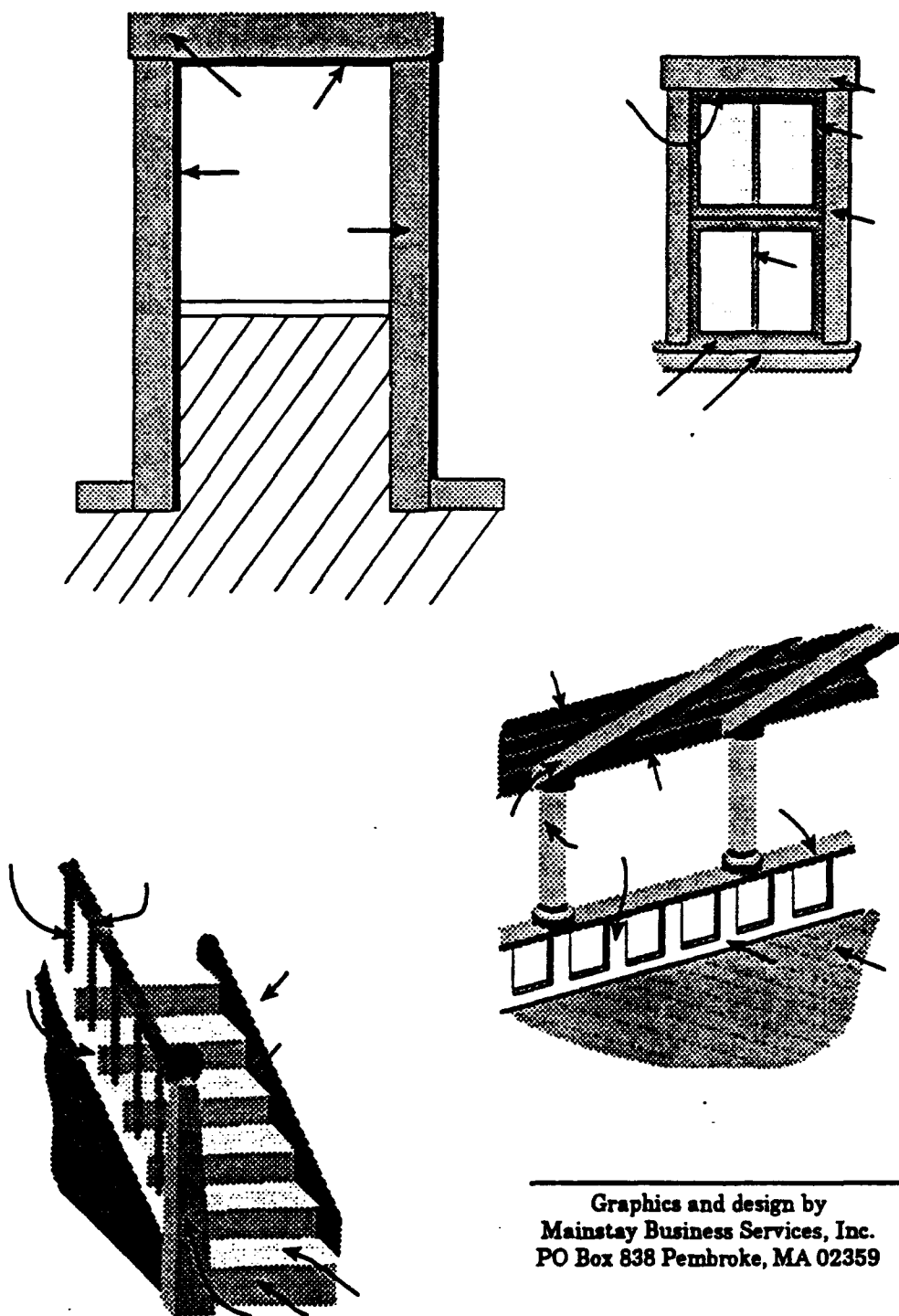
**Master Kit**

for those interested in becoming a lead hazard inspector

**Water Test Kit**

**Inspectional Services**

## Some Recommended Areas to Test



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# **THE LEAD DETECTIVE**

Lead Paint Detection Kit



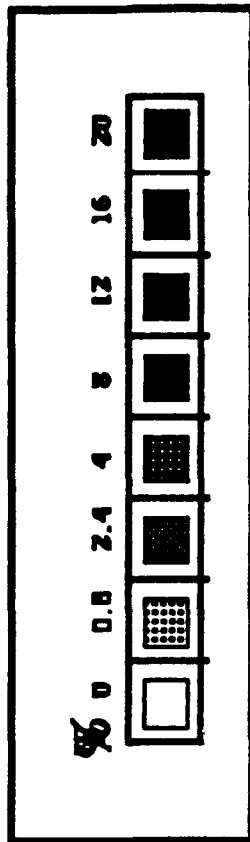
**Detects lead in paint down to  
1% by approved state method**

until the solid has completely dissolved before use. Mark down the date you prepared the solution, and an expiration date 6 weeks in the future.

Lead is detected by applying a few drops of sodium sulfide solution to the paint. The black color indicates the formation of lead sulfide and is a positive test for the presence of lead above 4%. Between 2-4% lead there will be a color change from dark gray to black. Below 1% there may be a light gray color formed and this should not be interpreted as an absolutely positive reaction. Modern paint uses metals like titanium dioxide that turn a gray color when reacted with sodium sulfide.

It may take a couple of minutes for the paint to blacken. Check both surfaces of a chip. Cleave the chip (use the straight edged razor blades supplied) to test paint layers sandwiched in between. Use the plastic tweezers as a convenience in handling your paint chips. Cut a groove through a surface in a diagonal or V-shape. Apply solution and check for color change. You may want to use the magnifying glass supplied to examine your work.

Lead Color Chart



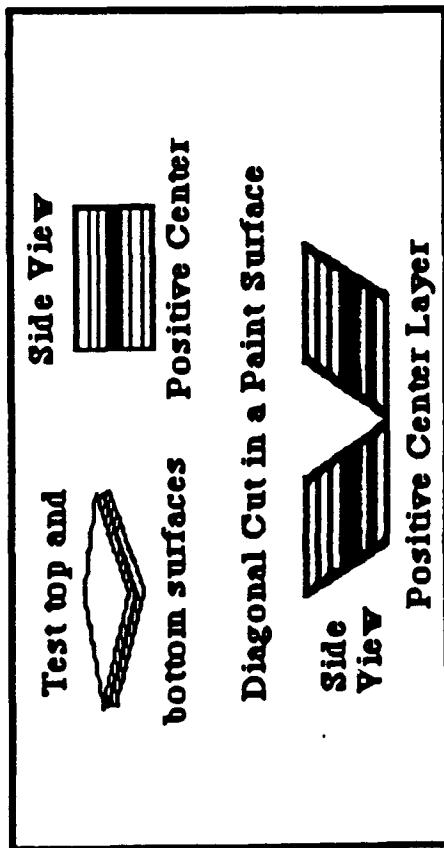
### Color Changes in Paint of Established Lead Content

Be careful when applying sodium sulfide to the paint chip or painted surface tested that you keep the dropper tip clean. If you touch the dropper tip to a paint sample containing lead you may contaminate the solution and invalidate your future results.

### DO NOT JUST TEST THE PAINT SURFACE

Lead layers may be in between non-lead paint. Primer can contain lead while outer coats are lead free. Do the test under good lighting. Dark paint can obscure the black color. Buried lead layers are potentially just as toxic as surface lead paint.

## Testing Paint Chips and Surfaces



Included at the bottom of the kit is a piece of leaded paint to be used as a reference for the color change. This will serve as a reference check that the test is working properly.

Try to test paint in inconspicuous locations. This test will discolor woodwork, so either use a paint chip or work carefully. You can paint over any cut in the paint after you wash the area with soap and water.

## SODIUM SULFIDE HAS A LIMITED LIFETIME

Keeping the bottle stoppered, out of the light and refrigerated will extend its shelf life. This pertains to

both the solution and solid form. Use the testing solution at once if possible. If you run out of solution, or cannot for some reason do the testing in the allotted time a reorder card for additional material is supplied with the kit.

## Other Considerations

Lead was added to paint in the past in the form of organic compounds to add brightening and luster to the paint. Other heavy metals such as zinc, titanium, and barium have been added but none of these reacts with the sulfide to give a black precipitate. Other metals used such as cadmium, chromium, cobalt, iron, manganese, magnesium, mercury, molybdenum, and nickel were generally added to pigments in amounts under 1%. Black sulfides are formed by iron, mercury, and molybdenum but in the quantities they were used in the past they will not test strongly positive.

Copper also forms a black sulfide, but it was used only in paint that required strong anti-fouling capability, such as that used in ocean going ships. If you test wood that has been varnished, or treated with copper sulfate, or where copper based stains are used you will get a false positive reading.



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### Vita

Mr. Lynn S. Hill was born on 27 June 1959 in Salt Lake City, Utah. He graduated with Honors from Viewmont High School in Bountiful, Utah in 1977. After performing voluntary service for his church for two years in Mexico, he attended the University of Utah and earned a Bachelor of Science degree in Chemical Engineering in 1985. Upon graduation, he accepted a position in civil service at Hill AFB, Utah. He began his career in the Material Management Directorate where he worked with 20mm and 30mm ammunition and cluster bombs. The majority of his time was spent working on the transfer of the Combined Effects Munition from Systems Command to Logistics Command.

Mr. Hill joined the newly formed Environmental Management Directorate in 1988. He first worked in plans and programs which provided a good overview of the work being done in the directorate. He was then assigned to manage the Environmental Compliance Assessment and Management Program for Hill AFB. In 1990 he was promoted to Chief of the Environmental Compliance Division where he remained until entering the Engineering and Environmental Management program at the Air Force Institute of Technology in May 1992. He obtained his Professional Engineer license in Chemical Engineering from the State of Utah in 1991.

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